VOLUME 58 [W. B. No. 1034] NUMBER 12

MONTHLY WEATHER REVIEW

DECEMBER, 1930

CONTENTS

	Page
Weather recurrences and weather cycles. (2 figs.) Sir Richard Gregory	483
Are meteorological sequencies fortuitous? (3 figs.) C. F. Marvin	490
Aerological observations made with a captive balloon from a moving ship. (4 figs.) Andrew Thomson	494
Meteorology and seasonal weather forecasting; annual progress report of the Scripps Institution of Oceanography. Geo. F. McEwen and A. F. Gerton	495
The weather of 1930 in the United States. (2 charts.) A. J. Henry	496
Preliminary statement of tornadoes in the United States during 1930. Herbert C. Hunter	497
NOTES, ABSTRACTS, AND REVIEWS:	Page
Dr. Geo. C. Simpson on thunder and lightning. *Abstr.* A. J. Henry	497
E. M. Keyser on An Inland Empire long-period rainfall riddle. *Note.* Carleton P. Barnes	498
Dr. Geo. C. Simpson on the climate during the Pleistocene Period. *Note.* A. J. Henry	498
K. Knoch and E. Reichel on the distribution and annual march of precipitation in the Alps. Sigismond R. Dietrich	499
BIBLIOGRAPHY	499
SOLAR OBSERVATIONS	500
AEROLOGICAL OBSERVATIONS	501
WEATHER IN THE UNITED STATES	503
WEATHER ON THE ATLANTIC AND PACIFIC OCEANS	505
CLIMATOLOGICAL TABLES	509
CHARTS I–XI.	

UNITED STATES DEPARTMENT OF AGRICULTURE
WEATHER BUREAU
WASHINGTON, D. C.

For sale by the Superintendent of Documents, Washington, D. C. - - - - - - - - - - - - See page 4 of cover for prices

CORRECTIONS

Volume 55, August, 1927, page 349: In Table 1, under caption "St. Louis," column headed "Warm," in the first line "1891" should be "1901," and in the next column "5.4" should be "5.7."

Volume 58, July, 1930, page 277: First column, insert "Southbound" in boxhead; second column, insert "1930" between lines 18 and 19 (counting from bottom); fourth column, Apr. 15–21, 1930, change "67.8" to "76.8"; next column, Mar. 4–10, change "76.4" to "74.6"; same column, Apr. 15–21, 1930, change "77.6" to "77.5"; third column from end, Oct. 15–21, 1929, change "91.1" to "81.1"; last column, May 27–June 2, 1929, change "80.0" to "82.0"; footnote 1, change "Aug. 10" to "Aug. 12."

Volume 58, August, 1930, page 332: First column, seventh line, the sentence beginning "Rain began at 6.15 p. m.," and continuing to the end of the paragraph, should be transposed to the next column, immediately following the paragraph in small type.

MONTHLY WEATHER REVIEW

Editor, ALFRED J. HENRY

VOL. 58, NO. 12
W. B. NO. 1034

DECEMBER, 1930

CLOSED FEBRUARY 3, 1931
ISSUED MARCH 7, 1931

WEATHER RECURRENCES AND WEATHER CYCLES[1]

By Sir RICHARD GREGORY, D. Sc., LL. D., President

[An address delivered before the Royal Meteorological Society on January 15, 1929]

Speculations and explorations relating to cycles of natural phenomena have always been of popular interest; and even when the evidence relating to them is tested by statistical standards of correlation coefficients their study is of value, however discouraging the results may be. It seems worth while, therefore, to devote my address this year to a general description of some weather recurrences and weather cycles which have at various times been accepted as articles of belief or derived from rigorous examination of evidence. From a strictly scientific point of view, it may be thought that no cycle is of substantial interest unless the proximate or ultimate cause of it is understood. Such a view can not, however, be maintained, particularly in meteorology, in which purely empirical knowledge may be the basis of methods of forecasting weather. The waxing and waning of solar activity in a period of about 11 years can be used to predict variations of solar radiation with fair precision, yet we do not know the cause of this cycle any more than we know the cause of gravitation which determines the movements of the planets. The first duty of science is to collect facts, and if these lead to a hypothesis, to test by observation any predictions suggested by it. When prediction is confirmed by sufficient experience, the hypothesis may be raised to the dignity of a theory, or even a law of nature.

With the generous aid of our encyclopedic secretary, Dr. C. E. P. Brooks, I am able to present a general survey of some studies of cycles or periodicities of weather from the point of view of possible forecasting. He has, however, himself remarked that the search for the golden cycle in weather is similar in its history to the search for the philosopher's stone—it has not been found, and we are more and more compelled to the belief that it does not exist. Periodicities in weather there undoubtedly are, but they are usually either so small in amplitude as to be of academic interest only, or they show baffling changes of phase and amplitude.

If in what I say I may seem to deal too critically with some beliefs which are still cherished by many amateur meteorologists, as well as by the general body of the public, my excuse must be that in these matters there is a very real danger of misconception. In judging the work of an official meteorological service there is a tendency to forget the successes and remember only the failures; whereas the prognostications which depend on wise saws and cycles receive more lenient treatment from the public. The failures are forgotten while the occasional successes are proclaimed from the houstops. Perhaps it is our habit of treasuring rarities which is responsible.

7-DAY RECURRENCES

There is a general popular belief in the existence of a 7-day weather recurrence, but this is probably due to the 7-day week, which impresses Saturday and Sunday rain disagreeably or otherwise on the memory of holiday makers and amateur gardeners, rather than on the existence of any marked periodicity of this length. In Australia, for example, there is a saying that if it rains on a Saturday it will rain on the next six or seven Saturdays. There does seem to be a little evidence in support of this belief, which is by no means always the case in weather proverbs, for a 7-day periodicity has frequently been brought forward in meteorological literature.

The most thoroughgoing investigation was described by A. Defant[2] in 1912. At individual stations the vagaries of the weather are too great to permit of systematic treatment, so Defant took as his basis the average rainfall on each day at some hundreds of stations in each of a number of countries. The laboriousness of the investigation limited it to a single year (1904), but the results were very far-reaching. In the Argentine he found that the rainfall undergoes marked variations, which result from the superposition of four waves having lengths of 7.1, 12.0, 16.8, and 31.2 days, the measurements being accurate to 10 per cent. In Australia he obtained four waves of almost identical length, 7.2, 12.1, 16.4, and 31.2 days. From the lengths of these periodicities, and the rate at which they moved from west to east, Defant proceeded to some remarkable conclusions which made them an integral part of the dynamics of the atmosphere; here it is sufficient to note their existence and the fact that the 7-day recurrence was by far the most imposing. In the Northern Hemisphere, with a different land and sea distribution, he also found four periodicities in the grouped values of daily rainfall for western United States, Europe, and Japan, of 5.7, 8.7, 12.7, and 24.5 days, respectively. These also move round the earth from west to east and form part of an exact dynamical scheme. Thus Defant draws for us his picture of an ordered rhythmic world.

Defant's system was ordained when the earth was born and the continents appeared above the oceans; Dr. J. R. Ashworth[3] gave us last year a glimpse of the power of man to modify the order of nature and introduce a weekly periodicity of rainfall. His contention was that "in a confined manufacturing area, such as the town of Rochdale, with a large number of factories burning quantities of coal of the order of 500 to 1,000 tons a day, it is not unlikely that the volume of heated gases which rises is

[1] Reprinted from Quart. Jour. Royal Meteorological Soc., April, 1930, vol. 56; pp. 103-120.

[2] Die Veränderungen in der allgemeinen Zirkulation der Atmosphäre in den gemässigten Breiten der Erde. Wien, SitzBer. Akad. Wiss., (2a), 121, 1912, p. 379.

[3] London, Q. J. R. Meteor. Soc., 55, 1929, p. 341.

sufficient to give that uplift to the atmosphere which is required to provide an increase of rain." In support of this conclusion he produced a table showing that on Sundays, when the mills are closed down, the average rainfall at Rochdale is less than on any other day of the week, whereas at Stonyhurst, remote from any large manufacturing center, Sunday rainfall, though still below the average, is greater than that of Friday. The resulting discussion revealed two opposing camps; one thought that the result was probably real, the other that it was simply due to errors of sampling.

Doctor Ashworth's 7-day periodicity, whether real or not, is too slight to be appreciable to the "man in the street," and has no value for forecasting. Defant's 6 or 7 day periodicities required elaborate arithmetic to magnify them up to the stage when they became visible to the human eye. This does not presage well for the success of forecasts based on short periodicities, the most familiar of which are those formerly published in the Daily Mail, and described by one of their supporters as a "billion times better than fortuitous predictions" and as "a notable advance in meteorological science." These were examined impartially by Capt. C. J. P. Cave,[4] who, after giving the results of a number of careful comparisons between forecasts and the observed weather, wrote: "It would appear, therefore, from the foregoing considerations that the forecasts, even for one week ahead, have not any success. They are not, in fact, any better than could be obtained by purely fortuitous predictions, and they agree with what one would expect from chance in a very marked way."

The application of short-period weather cycles to the elucidation of variations in the distribution of pressure from day to day has reached its greatest development in the hands of L. Weickmann.[5] The pressure variations at any one station are regarded as made up of a number of waves of various lengths. The combination of these waves gives a curve which is at first sight irregular, but close examination shows that certain series of day-to-day variations can be divided into two parts, the second of which is a reflection of the first. Reflection may be either single, as if the first half had been drawn and the paper folded over at the point of inflection while the ink was still wet, or double, the curve being not only reflected but also inverted.

If the same point of single reflection occurs at a number of stations, we have a series of daily weather charts which, after the date of reflection, are repeated in inverse order, and Weickmann illustrates a remarkable series of such charts extending from May 1 to July 11, 1922, and symmetrical about June 9. When such a series is established it obviously offers great prospects for successful forecasting, but the difficulty is to discover the points of reflection in time to be of service.

MONTHLY RECURRENCES

The monthly cycle of changes of the moon is believed by many people to be associated with changes of weather. As the moon is chiefly responsible for the rise and fall of the tides, it would seem reasonable to suppose that the earth's atmosphere is affected in the same way, and that there are air tides which may vary through the lunar month, like the spring and neap tides of the sea. Such atmospheric tides have indeed been detected, but they represent a difference at Greenwich of appreciably less than one-thousandth of an inch in a barometric reading, and are, therefore, scarcely worth considering as a sign of change of weather or a factor in forecasting.

As on the average our weather changes every four days, it is not surprising that such changes should occasionally coincide with changes of the moon which occur every seven days. Any success achieved by weather prophets who base their predictions upon the time of day when the moon enters one of its four quarters must, therefore, be attributed to the laws of chance and not to any actual relationship. Even when weather does change with change of moon, there is no regular cycle of weather conditions corresponding to the monthly cycle of lunar phases.

A subject which was given much attention last year is the recurrence of the same kind of weather at the same date in successive years. Here again popular imagination is apt to seize upon a few chance coincidences and to magnify them into a fixed law, such as the belief that Good Friday is always fine. In 1927 Mr. Milward stated in the Meteorological Magazine[6] that there was a definite tendency for storms to occur in the middle of the months rather than at the beginning or end, and he supported his thesis with what seemed like strong statistical evidence. Faith has been defined as "the art of believing that which we know to be untrue"; and faith in statistics needs to be highly developed to make such conclusions convincing.

ANNUAL PERIODS

Though weather is independent of the moon's movements or aspects, the same kind of weather tends to recur at definite dates annually on account of the succession of changes in the sun's position. Each year the seasons—summer and winter—come round with some approach to regularity, while spring and autumn also have their characteristics. In addition to the four seasons, a cold spell has been stated to occur regularly early in May, and has been associated with the so-called "Ice Saints." Various explanations have been offered to account for this cold spell, the most popular being that in the course of the regular annual series of pressure changes which result from the increasing power of the sun in spring, an anticyclone develops over northern Europe at the time and causes a period of northeasterly winds. Another cold spell is supposed to occur in June, caused by the development of monsoon winds blowing into the interior of Europe.

The chief explorer of these regular spells was Alexander Buchan[7] who defined them as follows: "Deductions from all observations hitherto made show that there are certain periods more or less well defined when the temperature, instead of rising, remains stationary or retrogrades instead of falling, stops in its downward course, or even rises, and at other times falls or rises respectively for a few days at a more accelerated speed than usual."

Buchan enumerated as many as nine such periods, to which he assigned the following dates:—

Cold periods	Warm periods
1. February 7–14.	1. July 12–15.
2. April 11–14.	2. August 12–15.
3. May 9–14.	3. December 3–14.
4. June 29–July 4.	
5. August 6–11.	
6. November 6–13.	

These 9 periods were deduced from observations in Scotland during a period of 10 years in the middle of the nineteenth century. In spite of this limitation, however,

[4] Nature, 109, 1927, p. 52.
[5] Wellen im Luftmeer. Neuere Untersuchungen uber Gesetzmässigkeiten im Gange und in der Verteilung des Luftdruckes. Leipzig, 1924.
[6] Vol. 62, 1927, p. 229.
[7] Edinburgh, J. Scot. Meteor. Soc., 2, 1869, p. 4.

they have been assumed by many newspaper correspondents to be equally valid for the temperature of London in the twentieth century. Such an assumption is quite unwarranted, and Buchan, if he were alive to-day, would be the first to reject it. No scientific evidence has ever been adduced that cold or warm periods have any tendency to occur in London on Buchan's dates.

LONG-PERIOD CYCLES

From these considerations of belief and evidence in weekly, monthly, and annual recurrences of similar weather we may pass to cycles having periods of several years. A lunar cycle which may have suggested weather cycles is that which determines eclipses. The Chaldeans and the Egyptians knew that eclipses recur after an interval of a little more than 18 years, and this cycle, known as the Saros, formed the basis of their very successful eclipse predictions. The cycle was discovered thousands of years before the astronomical movements which determine it were understood, but it was established as the result of observation; and no similar evidence is available upon which a related weather cycle can be based. It is true that H. C. Russell [8] in 1896 concluded from an inquiry into droughts extending over a period of a thousand years, particularly those in New South Wales in a period of 108 years, that the records fitted into a cycle of 19 years but this cycle does not stand the test of critical examination.

Doctor Russell suggested that the ancient Egyptians knew of the 19 years' cycle and that Joseph was versed in the wisdom of the priests and therefore able to predict Pharaoh's drought. He regarded Elijah's prediction as a repetition of this drought 49×19 years after it and Elisha's as 19 years after Elijah's, but the factor might just as well have been 14 instead of 19, as this was apparently the cycle upon which Joseph based his long-range forecast. It will be remembered that Pharaoh dreamed that seven fat kine came up out of the river, followed by seven lean kine, which devoured the fat kine. Then he dreamed that seven ears of corn came up upon one stalk, rank and good. Then seven thin ears and blasted with the east wind came up after them, and devoured the seven good ears. Joseph interpreted the dream thus: "Behold there come seven years of great plenty throughout all the land of Egypt. And there shall arise after them seven years of famine; and all the plenty shall be forgotten in the land of Egypt; and that famine shall consume the land." As we know from Biblical writ this forecast was successful, and the probable basis for it was a weather periodicity of about fourteen years. The periodicity could not have been very highly developed, or it would have been common knowledge, but it must have been sufficiently well marked to influence the general character of the succession of years.

Since that time many attempts have been made to discover weather cycles which can be used for long-range forecasting, but in none are prediction and fulfilment combined so dramatically as in the story told in Genesis. This cycle and some others already mentioned have received much popular attention; and most of them are in a different category from those which have merged from close meteorological inquiry.

Every year the weather is in some sense abnormal, but the past 12 months have given us rather more than our fair share of extremes, beginning with the most severe winter since the famous frost of 1895, continuing through several long periods of drought to the rainiest November and stormiest December on record. Unusual weather always leads to much discussion in the press of the time-honored subject of weather cycles, and 1929 was no exception. The point that the interval of 34 years since 1895 was within a year of the famous Brückner cycle was not missed, and the spells of cool rainy weather which tempered the dryness of spring and summer have been widely hailed as manifestations of the "Buchan cold spells." In fact, Buchan's credit soared so high that one enthusiast advocated the dethronement of St. Swithin, whose 40 day prognostic has long been exploded, in order that his place in the calendar might be given to St. Buchan.

BRÜCKNER'S CYCLE

Alone among modern weather cycles, that of 35 years has a background of tradition, for it was described by Sir Francis Bacon before 1625. Many of you are familiar with the passage from his essay "On Vicissitudes of Things."

"There is a toy, which I have heard, and I would not have it given over, but waited upon a little. They say it is observed in the low countries (I know not in what part) that every 5 and 30 years the same kind and suit of years and weathers comes about again, as great frosts, great wet, great droughts, warm winters, summers with little heat, and the like, and they call it the prime; it is a thing I do the rather mention, because, computing backwards, I have found some concurrence."

This weather cycle was rediscovered and carefully investigated by the late Dr. Eduard Brückner, then professor of geography at the University of Bern, and it is now known generally as the Brückner cycle. His great work, Klimaschwankungen seit 1700, nebst Bermerkungen über die Klimaschwankungen der Diluvialzeit, published in 1890, has become a classic for the patient collection and analysis of material from a great variety of sources. He studied all the long records of rainfall, pressure, and temperature available at the time, and carried the record back into earlier centuries by utilizing the variations of level in the Caspian Sea and other lakes in inclosed basins and in the great river systems of the world, the historic variations of ice conditions on the rivers of Europe, the dates of the wine harvest and the frequency of severe winters. From all this material he deduced the existence of a long succession of cycles—series of generally warm and dry years alternating with series of generally cool and rainy years. From 1020 to 1890 A. D. he found 25 cycles, giving an average length of 34.8 years, but the individual cycles varied between 20 and 50 years. With this in mind we must not expect too much from the Brückner cycle, for so great is this variation that only one cycle out of five comes within two and one half years of the expected length. When in addition one remembers that the amplitude of the variations is so small that in meteorological statistics the existence of the cycle can only be seen at all as the result of extensive smoothing, it becomes obvious that the Brückner cycle is useless for the purpose of making long-range forecasts of weather, and the interval of 34 years between the cold winters of 1895 and 1929 takes its proper place as a mere coincidence.

Brückner himself was far from claiming the mathematical regularity for his cycle that such exact recurrences would require, for he wrote:

"This is no single periodical meteorological phenomenon, which must fulfil itself with mathematical exactitude from one occurrence to another. Of the reality of a marked annual period of temperature or of rainfall there can not be the slightest doubt, and yet we see the epochs

[8] Roy. Soc. New South Wales, June 3, 1896.

from year to year fall not exactly on the same months, but now on the one, now on the other month, owing it may be to the influence of disturbing factors, which enter differently from year to year, or it may be to certain accidents. It would be very remarkable, if such accidents did not enter into our secular variations."

The true value of Brückner's work lies in a different direction. Although the amount of rainfall may vary widely from one year to the next, the quantity of water which is stored up on the land areas, in the soil, in lakes, and in glaciers, varies far more slowly. This stored water is not so closely related to the rainfall of the 1 preceding year, as to the average rainfall of the 10 preceding years, and if these 10 years fall in the wet half of a Brückner cycle, the quantity of stored water will be great. Again, in the dull rainy countries of northwest Europe, warm dry years are favorable for crops and vegetation, and on the whole the dry warm half of a Brückner cycle will yield better crops than the cool wet half, although there may be wide variations from one year to the next. An agricultural community must take the bad years with the good, and trust to the surplus from a rich harvest to tide over a year of dearth, but at the end of the warm half of the cycle the community will be prosperous, while at the end of the cold half it will be poor. Hence waves of emigration and the movements of peoples are closely related to climatic cycles such as Brückner's, which in this way may leave their mark on history. That, and not long-range forecasting, is the rôle of the weather cycle.

This view of its importance in economic life was in fact taken by Brückner himself, for he concluded his great work with the following words:

"I have attempted to sketch a picture of the climatic variations through which our earth has passed in the last centuries. Like the wheels of a clock the different meteorological elements engage with one another. We see the wheels turn and the hands move in predetermined rhythm, but the driving force of the spring is hidden from us. We can only recognize its effect and infer from it the powerful strength of the force. It raises the levels of the lakes, the rivers, even the sea itself, it pushes forward the glaciers and hastens the ripening of the plants. It goes deep to the root of human life, for it greatly influences traffic, husbandry, and health, and even repeats itself in theories and scientific observations. Only, itself, the cause of the climatic changes, we do not know."

This idea was further elaborated in the United States by Henry Ludwell Moore, a professor of political economy, who turned meteorologist for the occasion, and in his well-known book, "Economic Cycles: their Law and Cause" (New York: Macmillan, 1914), he summarized his conclusions as follows:

"The rhythm in the activity of economic life, the alternation of buoyant, purposeful expansion with aimless depression, is caused by the rhythm in the yield per acre of the crops, while the rhythm in the production of the crops is, in turn, caused by the rhythm of changing weather which is represented by the cyclical changes in the amount of rainfall. The law of the cycles of rainfall is the law of the cycles of the crops and the law of economic cycles."

Moore discovered two periodicities in the rainfall of the Mississippi Valley from 1839 to 1910, one of 8 years and the other of 33 years, and the latter may reasonably be identified with the Brückner cycle. Its exact length is a matter for dispute, different authorities giving various values ranging from 33 to 36 years, but this uncertainty need not disquiet us. The noninstrumental records, like severe winters and fluctuations of water level, are by their nature somewhat vague; even the records of the annual rings of tree growth have not the exactitude of good observations with meteorological instruments. On the other hand, trustworthy instrumental observations go back little more than a hundred years, and cover only three or at most four cycles, a period which is not sufficient for an accurate determination of length. The general average of all the estimates, however, can not be far from Brückner's original figure of 34.8 years, which thus gains in probability from the attempts to improve or supplant it.

Further inquiries, however, reveal departures from this estimate. The Brückner cycle has received a great deal of attention, but this is probably due more to the fact that it has a name and a history than to its intrinsic importance. Brunt's elaborate examination of long meteorological records in western Europe[9] did not display the 35-year periodicity as any more noteworthy than several others; in fact, it could only be found at all in 6 of the 12 long records examined. Brückner took his material largely from the records of severe winters in Europe, but the late Dr. C. Easton, who reexamined the periodicity of winter severity, using data far more complete than Brückner's, found no evidence of a 35-year cycle, giving his vote instead to a periodicity of 89 years with a well-marked half cycle of 44½ years.[10] He summarized his conclusions as follows:

"Within each interval of 44½ years, to begin with A. D. 759.5 (1872.0) the first half is colder than the second." To this rule there have been no exceptions since 1200.

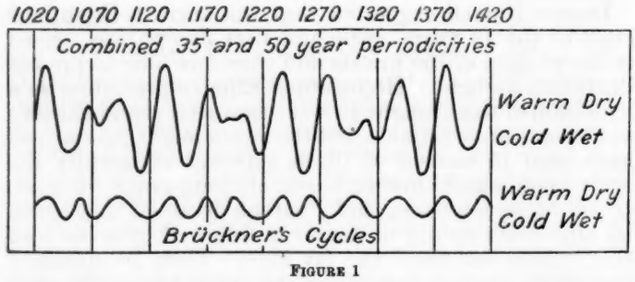


FIGURE 1

"Within each interval of 89 years, to begin with the year 759.5 (1827.5) the first half is colder than the second." Since 1116 there has been only one exception.

It should be noted that both these rules would give a period of cold winters commencing in 1917.

50-YEAR CYCLE

In the rainfall of Great Britain the Brückner cycle is far less important than one of 50 years. The authoritative pronouncement made by the council of the Royal Meteorological Society in the matter of the supposed influence of broadcasting on weather contained a passage pointing out that groups of wet years in England have occurred about 1770, 1821–1830, 1871–1880, and 1922–1928, four recurrences at intervals of about 50 years, separated by groups of dry years in 1741–1750, 1801–1810, 1851–1870, and 1891–1910, the inference being that the wet years since 1922 were due to some natural period of oscillation of the rainfall, and not at all to the relatively small electrical disturbance of the ether by human agencies.

Before leaving the subject of the 35 and 50 year weather cycles, mention may be made of one feature of

[9] London, Q. J. R. Meteor. Soc., 53, 1927, p. 1.
[10] Periodicity of winter temperatures in western Europe since A. D. 760. Sci. Proc. A. Akad. Wetenschap, Amsterdam, 20, 1918, p 1092.

Brückner's results which is not without interest. He found that the length of his cycle varies from 20 to 50 years, but it does not seem to have occurred to him that this variation most probably came about because he was actually dealing with two periodicities of about the same amplitude but of different lengths. Figure 1 shows a series of alternating warm and cool periods as determined by Brückner from the incidence of severe winters between A. D. 1020 and 1420, and for comparison the curve obtained by combining two such periodicities (actually 35 and 50 years). The agreement is reasonably close, and suggests that the Brückner cycle is in fact a composite affair made up of two periodicities of about those lengths.

THE 11-YEAR SUN-SPOT CYCLE

There is one other cycle which has claimed great attention in relation to weather, namely, the sun-spot cycle of 11 years. The literature of this subject is enormous, but critically examined, it may be reduced to very little. Sun-spots are a useful index of the activity of the sun, and they go through a not very regular cycle with an average length of 11.125 years. Taking account of the change of polarity discovered by Dr. G. E. Hale,[11] it is more accurate to say that sun-spots go through a double cycle of 22.25 years. In terrestrial phenomena, these changes of solar activity are accompanied or closely followed by fluctuations in the elements of terrestrial magnetism and by variations in the frequency of auroræ. E. J. Lowe, after an elaborate investigation of the dates of all droughts and frosts of historic times in Britain of which he could find mention, concluded that there was an 11-year cycle of the seasons with maximum variability at the end of each century.[12] Writing in May, 1880, he stated that the drought which had begun in October, 1879, could be expected to last three years, and that "the intensity of the winters about 1896 will be greater than those we have just experienced." Actually the drought ended at the close of the month in which he wrote, but 1896 might be taken as a fairly close estimate for the cold winter of 1894–95.

In matters of weather, a connexion with temperature was first suspected by Riccioli as early as 1651, and was clearly demonstrated, for tropical regions, by W. Köppen in 1873. There also appears to be a fairly close relationship between the sun-spot number and the rainfall in certain parts of equatorial Africa, especially the plateau of Lake Victoria; and the 11-year cycle in the level of this lake, which rises and falls with the rise and fall of solar activity, is one of the best known and most striking illustrations of the connexion between solar and terrestrial phenomena.[13] This is shown by Figure 2, which has kindly been supplied to me by the meteorological office. A similar relationship is found in Lake Albert and further south in Lake Nyasa, though in the latter it is somewhat obscured by the large annual variation in the level of the lake, and by other factors.

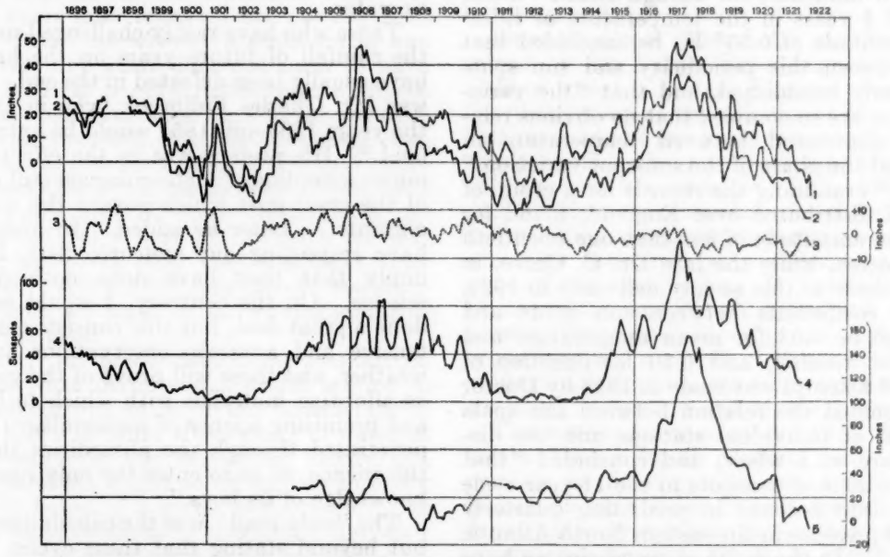


FIGURE 2.—Curves 1 and 2 monthly maximum and minimum lake levels in inches above or below zero level. Curve 3 rainfall Uganda, deviations from normal summed in overlapping periods of six months. Curve 4, monthly sun-spot numbers. Curve 5 mean level of Lake Albert in inches above zero level. (The above diagram was prepared from the original Memoir and published in this REVIEW 52:149—ED.)

In Great Britain the 11-year sun-spot cycle, like the Brückner cycle, is of little importance. Although we are undoubtedly governed in the long run by solar influences, these find their way from equatorial to temperature latitudes by many and sometimes devious routes—winds, ocean currents, etc.—so that their unity becomes lost and they appear as an irregular series of changes following no apparent law. For example, it was found by Dr. G. Hellmann that the rainfall of Europe has two maxima and two minima in each sun-spot period, and he explained this as due to the combination of two causes, the direct effect of the solar variations on the weather of Europe and the indirect effect due to changes at the equator extending their effect northwards.[14]

The pioneer in the investigation of the 11-year cycle in Great Britain was Alexander Buchan, who found evidence for its existence in the long record of rainfall at

[11] Sun-spots as magnets and the periodic reversal of their polarity. Nature, 113, 1924, p. 105.
[12] The coming drought, or the cycle of the seasons. London, May, 1880.
[13] London, Air Ministry, Met. Office, Geophysical Memoirs, No. 20, 1923.
[14] Untersuchungen über die Schwankungen der Niederschläge. Berlin, Veröff. K. Preuss. Met. Inst., Abh. 3, 1909–10.

Rothesay, in Bute, throughout the nineteenth century,[15] the heaviest rainfall coming about a year after the sun-spot maximum. He also found traces of a similar cycle in the rainfall of other stations in the western Highlands and the Hebrides, which confirmed the evidence of Rothesay, though the records were too short to provide independent evidence. Moreover, these stations being all in mountainous regions, Buchan inferred that the greater rainfall at sun-spot maximum must be due to a greater frequency of southwesterly winds at that time, and a subsequent examination of the wind records at a number of stations confirmed the inference.

Buchan's mantle in this respect fell upon A. MacDowall, who has published a number of short papers showing that there is a real sun-spot effect in the weather of western Scotland, though that effect is both smaller and more complex than Buchan supposed. Over the rest of the country, however, it is now recognized that sun spots have practically no influence, for though Brunt [9] found a periodicity of 11.4 years in the temperature of Edinburgh with an amplitude of 0.55° F., he concluded that the connection between this periodicity and sun spots was not at all clearly established, and that "the variations of temperature are so complex that no obvious relationship can be discovered between temperature in individual years and the phase of the sun-spot variation." Similarly F. Baur [16] examining the records for a group of eight stations well distributed over England, found for the 11-year cycle an amplitude of less than one-twentieth of a Fahrenheit degree, while the late Dr. C. Chree, in his presidential address to this society delivered in 1924, found correlation coefficients between sun spots and weather at Kew to be 0.03 for mean temperature and cloudiness, 0.04 for rainfall, and 0.10 for duration of sunshine. The last attempt was made in 1928 by Doctor Brooks,[17] who examined the relation between sun spots and pressure, both at individual stations and the distribution of pressure as a whole, and concluded "that at present the variations of sunspots in the 11-year cycle can not be taken into account in predicting quarterly mean deviations of pressure in the eastern North Atlantic or western Europe." In the realm of economics we have the well-known theory of Prof. W. Stanley Jevons,[18] published after his death in 1882, that financial crises are related to the sun-spot cycle:

"A mania is, in short, a kind of explosion of commercial folly, followed by the natural collapse. The difficulty is to explain why this collapse so often comes at intervals of 10 or 11 years, and I feel sure the explanation will be found in the cessation of demand from India and China, occasioned by the failure of harvests there, ultimately due to changes in solar activity."

When Stanley Jevons wrote that paragraph, the length of the sun-spot cycle was believed to be between 10 and 11 years; since then the cycle has been found to be rather more than 11 years, which to some extent destroys the value of the argument. Moreover, Sir William Beveridge,[19] in his well-known paper on Wheat Prices and Rainfall in Western Europe, found that except between 1632 and 1697 the periodicity of about 11 years was not particularly important in wheat prices, while over the whole interval from 1500 to 1869 its average length is 10.9 years, so that its connection with the sun-spot cycle is by no means certain.

[15] The rainfall of Scotland in relation to sun spots. Edinburgh, J. Scot. Meteor. Soc., 12, 1900-1901, p. 117.
[9] London, Q. J. R. Meteor. Soc., 53, 1927, p. 1.
[16] Washington, D. C., MONTHLY WEATHER REVIEW, 53, 1925, p. 204.
[17] London, Air Ministry, Met. Office, Professional Notes, No. 40, 1928.
[18] Investigation in currency and finance.
[19] London, J. R. Statist. Soc., 85, 1922, p. 412.

PERIODS OF TWO TO FIVE YEARS

Equally imposing in its bulk with that of the sun-spot cycle is the literature of cycles of two to five years. The suggestion has been made, notably by Defant, that there is a natural period of about three and one-half years in the oscillation of the earth's atmosphere, which requires to be set going by some vigorous impulse; Defant found such an impulse in a violently explosive volcanic eruption. Others, notably Sir Norman and Dr. W. J. S. Lockyer, saw in them yet another manifestation of solar influence, usually shown in the form of solar prominences. In some parts of the world, notably the East Indies, these periodicities of a few years are of undoubted value in forecasting the general rainfall some months ahead; in Great Britain they have at times reached a spectacular development, but always, just when they seemed to have established themselves thoroughly, they changed their length or their phase, or otherwise proved themselves unstable as water.

Those who have rashly challenged nature by predicting the rainfall of future years on the basis of such cycles have usually been defeated in the end. An early example was Mr. Charles Fullbrook, who in 1861 predicted that the years 1863 and 1864 would be extremely wet in England.[20] His preface was to the effect that with certain minor exceptions "meteorologists still remain as ignorant of the great laws which govern the weather as were the ancients." Later he added, "In making the remarks I have respecting our meteorologists, I do not mean to imply that they have done nothing to advance the science. On the contrary, I would say that they have done a great deal, but this consists chiefly in making extensive and accurate observations and records of the weather, and these will prove of the greatest importance, as affording materials with which to build up the noble and promising science of meteorology; but they have not penetrated through the absurdities that have mystified the science, so as to enter the only road which leads to a knowledge of its laws."

The "only road" was the calculation of weather cycles, but beyond stating that these cycles had been deduced on strictly scientific principles from the rainfall of 60 years, and that they correspond precisely with certain astronomical periods, the author does not give away trade secrets by stating their length. We may, however, penetrate his "mystery" by suspecting that cycles of three to five years played the major part. In spite of the author's weighty introduction, however, his calculations were seriously at fault, for 1863 was well below normal and 1864 was probably the driest year since the beginning of the nineteenth century. One is reminded of the remark of the Yankee at the Court of King Arthur that whenever Merlin issued a gale warning there was a week's dead calm.

To come to more modern and less assertive attempts we find that the Quarterly Journal for 1913 contains a detailed study by Mr. A. P. Jenkin [21] entitled "A 3-year period in rainfall," which began in hope and ended, as the late Mr. Carle Salter remarked in opening the discussion, in doubt and difficulty. More recent was Mr. J. Baxendell's contribution in the Quarterly Journal for 1925, on "Meteorological periodicities of the order of a few years, and their requisitely local investigation; with especial reference to the term of 5.1 years, in parts of

[20] The west and dry seasons of England, from the year 1846 to 1860, inclusive; their agreement with rule and system; with some remarks on the probable character of the following four years, 1861 to 1864, inclusive, and on the expected extremely wet season, founded on rules deduced from a long series of observations of the rainfall. Dallington, Hurst Green, Sussex, March, 1861.
[21] 39, 1913, p. 29.

Britain." [22] The latter paper embodies the results of a great amount of research into a single definite problem, with the result that we possess more exact information about the 5.1-year periodicity in British weather than about any similar phenomenon.

The story of the periodicities of two and five years, as unfolded by the late Carle Salter and J. Glasspoole,[23] begins in 1868. For 15 years, up to 1882, each fifth year (1872, 1877, 1882) was very much wetter than any of the remaining 12. Then this series broke down, but from 1889 to 1909 there was a most remarkable sequence in which every third year was abnormally wet. The years 1891, 1894, 1897, 1900, 1903, 1906, and 1909 were all wetter than the average; of the remaining 14, one was exactly normal and the others were all dry. The sequence of British weather seemed to have been revealed, but Dr. H. R. Mill pointed out in 1903 that caution should be exercised in accepting it. Though this curious and quite empirical 3-year recurrence went on, Doctor Mill three years later repeated his warning with greater emphasis. "As," he wrote, "a sequence of one wet and two relatively dry years does not seem to have held good before 1891, it is only reasonable to expect that it will cease to hold good some time in the future."

The warning was justified, for the sequence was already breaking down, but after 1909 it changed to an almost equally remarkable 2-year oscillation. From 1910 to 1922 the even years were all much wetter than the average, while the odd years were all dry with the sole exception of 1915, and even that year was drier than either 1914 or 1916. After 1922 this 2-year sequence broke down, and now we seem to have returned temporarily to the 3-year type.

Sir Gilbert Walker,[24] my predecessor in the presidential chair of this society, has performed a useful service to meteorology by setting out some of the considerations which have to be borne in mind when going in quest of meteorological periodicities, and explaining briefly and clearly some criteria which ought to be applied to every supposed periodicity before it is given to the world. He has also described some methods of shortening the labor in the calculation of periodicities without sacrificing reliability of results.

WEATHER CYCLES AND CROPS

On account of the importance of weather to agricultural operations and yields, many investigations have been made to discover periodicities connecting them. In his presidential address to this society in 1921 Mr. R. H. Hooker [25] gave a detailed summary of the various researches into crop forecasting. The best work has been done by a direct study of the relations between variations of weather and subsequent variations of crops—Mr. Hooker has himself provided a notable example of such research—but cycles have not been without their enthusiasts, without, however, any results of practical value being reached, one set of enthusiasts often conflicting with another. For example, Hooker remarked, "If I understand Moore's diagrams correctly, his cycles point to maximum crops at the critical dates indicated by Beveridge as years of dearth."

Hooker found the rainfall in the autumn of great importance for wheat growth and held that this was the most important season for wheat. The critical period was the thirty-seventh to the forty-fourth weeks in the calendar year. There is also a strong connection between the weather in which the seed wheat was grown and the yield of the crop from this seed. For wheat a lack of rain during flowering and hot weather during ripening is necessary for good quality, while for yield cool weather is desirable. This explains the sequence of good and bad years which has been observed for wheat. A bad harvest gives a good quality wheat and a good harvest gives grain which is less suited for seed. In 1906 Sir Napier Shaw [26] directed attention to a remarkable symmetry in the yield of wheat for eastern England between 1885 and 1905, which can be represented with great fidelity by a series of harmonic components which are integral fractions of 11 years. The periodicities having the greatest amplitude are those of 11, 3.7 and 2.75 years. The agreement maintained itself with fair precision until 1908, but after that date it broke down; the minima which should have occurred in 1911 and 1914–15 falling instead in 1910 and 1916, while the general run of the figures from 1907 onward is decidedly different from the run between 1885 and 1907, which they should have resembled.

Recently Ernst Rietschel,[27] analysing the results obtained by Sir Napier Shaw from the discussion of the yield of wheat in eastern England, was led to investigate the distribution of periodicities of three to three and one-half years and of two years in winter temperature over the whole world. His results, being based on a period of only 12 years, are of limited value, but are set out in great detail. He concludes that the three to three and one-half year period had the character of a standing oscillation, which he interprets as a characteristic of the general atmospheric circulation. It vanishes at points in the United States and North Africa and reaches maxima in Alaska, Greenland, Siberia, and Australia. The other periodicity has a length of about 2.2 years, and is more uniformly developed, spreading out north and south from the north temperate and southern tropical regions.

The methods now adopted at the Rothamsted Experimental Station for all accurate field experiments make it possible to discover with considerable precision the influence on crop yields of rain, temperature, sunshine, or any other meteorological factor that can be measured and expressed in figures. Dr. R. A. Fisher has already traced the connection between rainfall in the different months of the year and wheat yields under different fertilizer treatments; a similar investigation into barley yields has now been made. The effect of hours of sunshine on wheat yields has also been examined; the most striking effect is of autumn sunshine just before or just after the sowing of the crop; whether the benefit arises from the warming or the drying of the soil is not yet found. For the rest of the year, even in July, actual sunshine seems unimportant; the great weather factors seem to be the temperature and the rainfall.

Dinsmore Alter has devoted a great deal of attention to the investigation of periodicities in rainfall. Two papers of especial interest may be mentioned. In the first [28] Alter examined, among others, a composite record covering an interval of 173 years in northern Europe, and found periodicities of about 10 years and 15 to 16 years. These conclusions were confirmed by shorter records from the eastern United States and the Punjab, India. There was no trace of the 11-year sun-spot cycle, and on the European record, which alone was long enough to deter-

[22] 51, 1925, p. 371.
[23] London, Q. J. R. Meteor. Soc., 49, 1923, p. 207.
[24] On periodicity. London, Q. J. R. Meteor. Soc., 51, 1925, p. 337.
[25] Forecasting the crops from the weather. London, Q. J. R. Meteor. Soc., 47, 1921, p. 75.
[26] Shaw, W. N. An apparent periodicity in the yield of wheat for eastern England, 1885–1905. London, Proc. R. Soc., A. 78, 1906, p. 69.
[27] Rietschel, Ernst. Die 3-3½ jährige und die 2 jährige Temperaturschwankung. *Leipzig, Veröff. Geophys. Inst. Univ.*, Bd. 5, H. 1, 1929.
[28] Application of Schuster's periodogram to long rainfall records, beginning 1748, *Washington*, MONTHLY WEATHER REVIEW, 52, 1924, p. 479.

mine it, there was only a slight indication of a "Brückner cycle" of 37 to 40 years.

In the second [29] paper he applied the method of correlation to rainfall data for the British Isles from 1834 to 1924 and found a number of periodicities of which the most important were 24½, 41, and 51 years, which are in the ratio ¾, 1, and ¾. Others were slightly over 43 years and the Brückner cycle of 34 years. All these are submultiples of a major period of 613 years. Alter calculated the 6-monthly rainfall from the periodicities, and extended the calculated curve to 1940, and though he emphasized that "the future values are given for test purposes only," it is interesting to note that his test prediction indicates a remarkably low rainfall in the first half of 1929, followed by a recovery in the second half—and incidently a slight excess of rain in the first half of 1930, which is repeated here "for test purposes only."

LONG-RANGE FORECASTING BY WEATHER CYCLES IN SUBTROPICAL LATITUDES

It is in subtropical latitudes that rainfall cycles of a few years in length seem to offer the greatest prospect of practical utility. In Java they have been investigated by C. Braak [30] and later by H. P. Berlage [31] and tentative forecasts have been issued for some years. The dominant periodicity here is one of three years, but this breaks down from time to time and begins again at a different phase, so that the statistical result is a periodicity of between three and three and three-fourths years. It is probable that there is a local natural period of oscillation between the East Indies and Australia to which the succession of the seasons gives a length of exactly three years, but this oscillation is alternately set in motion and stopped by some more general cause which recurs at intervals of about three and one-half years or of some multiple of that. Berlage has discovered a cycle in the atmospheric and oceanic circulations of the Pacific which has a length of seven years, and this may be the more general cause which modifies the local 3-year oscillation. A picture of these swings may be given by supposing that a pendulum has a natural period of three seconds, but that the bob is struck from right to left every seventh second

[29] A group or correlation periodogram, with application to the British Isles. *Washington*, MONTHLY WEATHER REVIEW, 55, 1927, p. 263.

In southern Rhodesia Mr. C. L. Robertson [32] has been making tentative rainfall forecasts by a method of correlation similar to that employed successfully in India, and so highly developed by Sir Gilbert Walker. It is interesting to notice, however, that one of the terms of Robertson's equation is the rainfall of Rhodesia four years before, which has a correlation of —0.33 with the rainfall of the season to be forecast. This negative correlation points to a periodicty having a length of about 8 years or possibly of 2 to 3 years, or of both combined, so that the Rhodesian forecasts are in part based on cycles of rainfall.

In the rainfall, of Algeria [33] L. Petitjean has discovered periodicities of 6, 15, and 35 years, as a result of which the rainfall curve in its broad lines is symmetrical about 1903, that is, the rainfall of 1898–1902 resembles that of 1904–1908, 1894–1898 resembles 1909–1913, and so on. On the strength of this resemblance the author boldly prophesies the general course of rainfall in Algeria up to 1975, and foretells severe famines between 1940 and 1945 and between 1970 and 1975.

The most recent application of weather cylces to long-range forecasting in subtropical regions was made in Australia by Mr. H. A. Hunt,[34] who found evidence for a 4-year cycle in rainfall and temperature, which he attributed to a purely local chain of causes and effects. Some striking results were advanced, but the series of general rainfall values available in Australia appears to be too short as yet for them to be used with confidence in making predictions.

This seems, indeed, to be the chief conclusion to which a consideration of various weather cycles leads. They are either indefinite, or if they are expressed precisely they usually break down when tested over long periods. When a cycle has been found which is of real practical value in forecasting, it will be welcomed by meteorologists even though science may be unable to furnish any clue as to its origin.

[30] *Batavia, K. Mag. en Meteor. Observatorium. Verh.* no. 5. Atmospheric variations of short and long duration in the Malay Archipelago, and the possibility to forecast them. By C. Braak. Batavia, 1919.

[31] *Batavia, K. Mag. en Meteor. Observatorium. Verh.* no. 20. East Monsoon forecasting in Java. By H. P. Berlage. Batavia, 1927. (See *Meteor. Mag.* 62, 1927, p. 268).

[32] Robertson, C. L. The possibility of seasonal forecasting and prospects for rainfall season 1922-23. *Salisbury, Rhodesian Agric. J.*, 1922, pp. 648–655.

[33] Petitjean, L. Sur une périodicité et une symmétrie de la courbe des pluies à Alger. Application à la prévision des périodes sèches et pluvieuses en Algérie. *C. R.*, 185, 1927, pp. 472–473.

[34] Quart. Jour. Roy. Met. Soc. 55:323-330

ARE METEOROLOGICAL SEQUENCES FORTUITOUS?

By C. F. MARVIN

[Weather Bureau, Washington, January, 1931]

Any reader who expects this will carry an answer to the question raised in the title is destined to disappointment, but he may profit possibly by the information presented, which is the outcome of a file of correspondence with Mr. S. L. Moyer, civil engineer, interested in flood control and other hydrological problems.

Mr. Moyer says:

> The dilemma of contradictory weather cycles as shown by well authenticated data from two adjoining counties in the States of Washington and Idaho, may perhaps be explained by the examination of the premise which assumes periodicity.
>
> The existence of apparent rhythmic fluctuations in weather phenomena naturally suggests an assumption of periodicity; but to regard such periodicity as proven by the apparent rhythmic flow of the phenomena, is really quite unwarranted. It may possibly be true that haphazard contributions [i. e., departures from normal due to fortuitous influences C. F. M.], considered as resulting in accumulated departures from normal, may also display an apparent periodicity.

Without quoting his reasoning, he, briefly, assumed precipitation could be likened to the haphazard casts of four dice scored by the products of the points, and he adds:

> With this multiple haphazard premise in mind, 600 throws of four ordinary dice were made, the numbers exposed being multiplied together to arrive at a score. Theoretically, the mean or normal score for four dice in multiplication is 150.06, when the full range of opportunities is exhausted. For convenience, the normal was taken to be 150, and the excess above or shortage below this value was carried forward for each throw into a subtotal of accumulated departures. The annexed graph (fig. 1) gives a picture of the results of this process.
>
> This diagram suggests the unsoundness of assuming that an apparent rhythm proves periodicity; but, on the other hand, neither can it be said that the haphazard premise is demonstrated thereby. Each of these views has its value, and when the smoke of controversy clears away there may be reason to believe that the fluctuations in the weather arise out of both periodic and fortuitous sources.

On various occasions the writer has urged that perhaps the best way to examine the question of physical control upon the weather, as contrasted to fortuity, in the order of succession of meteorological data, consists in placing numbers which represent the meteorological data under examination on uniform balls (marbles or steel ball bearings). These are then thoroughly mixed by tumbling

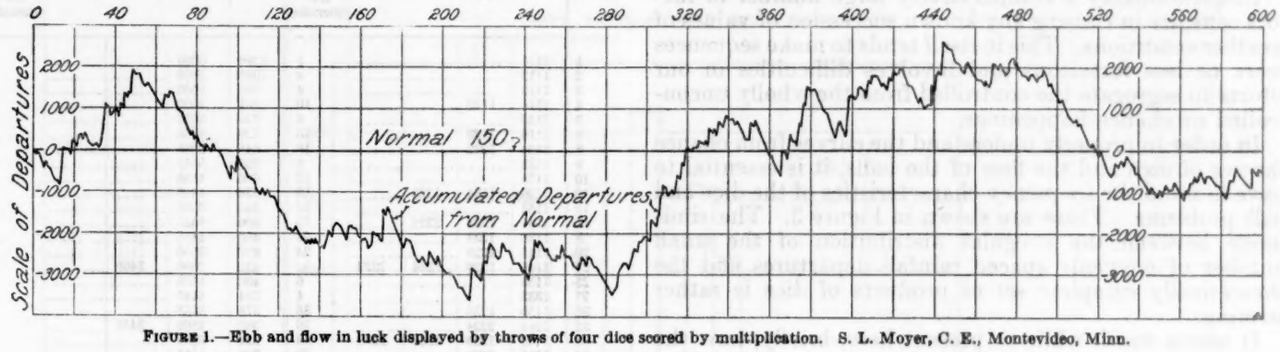


FIGURE 1.—Ebb and flow in luck displayed by throws of four dice scored by multiplication. S. L. Moyer, C. E., Montevideo, Minn.

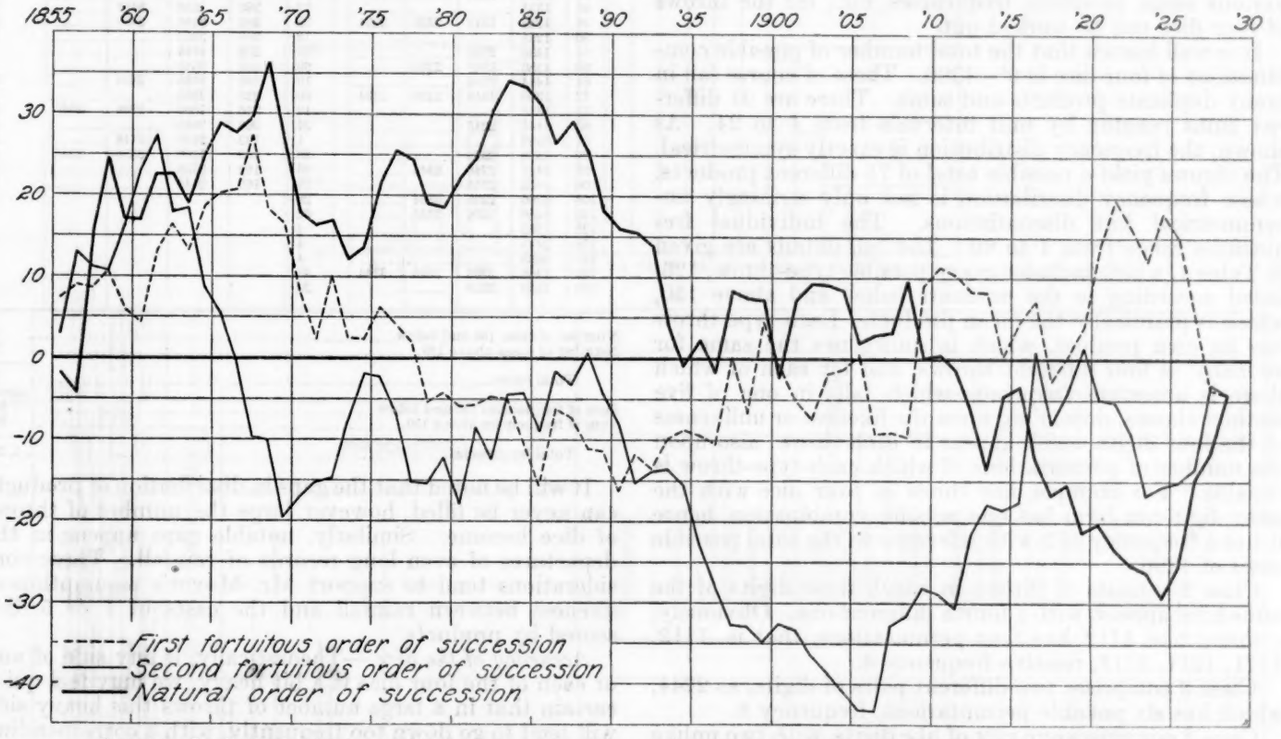


FIGURE 2.—Graph of accumulated sums of departure from mean of 74 years of rainfall record for stations at Peoria, Ill., St. Louis and Oregon, Mo.

about in an adequate container and poured out into a long V-shaped trough or groove, where the balls assume a perfectly fortuitous order of succession, which may be read from either end.[1]

The results of two runs of the balls are shown in Figure 2. The data are the mean values of annual precipitation for 74 years from three relatively nearby stations, namely, Peoria, Ill., St. Louis and Oregon, Mo., beginning 1856.

The heavy full line represents the accumulated sums of departures from the normal, 36.6 inches, based on the natural order of succession. The remaining lines represent the accumulated sums of the same departures in two fortuitous orders of succession.

The merit of the method of balls in introducing the element of chance in the order of succession is that none of the characteristic features of the numerical data, such as frequency distribution, standard deviation, normal, etc., are changed in the slightest. All remain unchanged except the order of succession.

If not designated on the diagram, who could pick out the natural from the chance order of succession? In the chance order of succession we imagine that the plus and minus departures are equally probable, and that the magnitude of the departures are questions of chance. The line of accumulated sums must therefore tend to cross and recross the base or zero line with frequency.

[1] Some 200 steel balls about seven-sixteenths inch in diameter have been numbered consecutively for this purpose from 1 to 99. A black or blank ball serves as 100 when needed. A second series of 99 balls bear the same consecutive numbers, but these balls are all colored brown or blue by heating. The color scheme is resorted to in order to facilitate separating the balls when less than 100 are desired. The purpose of this is to have individual balls that can represent any sequence of observational data from 1 to nearly 200 items, that is, the observations themselves are numbered consecutively from 1 up to the last observation. The necessary number of balls are chosen to represent the exact number of observations, and after pouring out in a chance order of succession the data are identified by choosing the departures from normal corresponding to the item of record represented by the particular ball in question.

It seems reasonable to expect that some useful information could be gathered from a further application of the methods described. Such studies should of course include analytical discussions of the effects of the so-called "laws of chance," which are words we use to comprise what we know about events which result from the operation of a large number of independent causes.

Unquestionably a comparatively large number of factors conspire in causing any known succession of values of weather conditions. This in itself tends to make sequences more or less fortuitous and involves difficulties in our efforts to segregate the controlled from the wholly uncontrolled or chance happenings.

In order to properly understand the curves from chance throws of dice and the flow of the balls, it is essential to have in mind the frequency characteristics of the dice and ball problems. These are shown in Figure 3. The similarity between the irregular distribution of the small number of unevenly spaced rainfall departures and the theoretically complete set of products of dice is rather striking.

It seems worth while to present here, briefly, how the various sums, products, frequencies, etc., for the throws of four dice can be worked out.

It is well known that the total number of possible combinations of four dice is $6^4 = 1296$. These of course fall in many duplicate products and sums. There are 21 different sums ranging by unit intervals from 4 to 24. As shown, the frequency distribution is exactly symmetrical. The throws yield a possible total of 75 different products, whose frequency distribution is not only strikingly unsymmetrical but discontinuous. The individual frequencies range from 1 to 60. The full details are given in Table 1, which includes every possible type-throw, 126, listed according to the products below and above 150, which is practically the mean product. Each type throw has its own product, which is sometimes the same for as many as four different throws, and for each of which there is a certain frequency which falls in one of five distinct classes, depending upon the likeness or unlikeness of the four digits which appear in each throw, also upon the number of permutations of which each-type-throw is capable. For example, any throw of four dice with the same digit can form but one possible combination, hence it has a frequency of 1 with reference to the total possible cases of 1296.

Class 2 consists of throws in which three digits of the same kind appear, with a fourth different one. Obviously, a throw like 1112 has four permutations, that is, 1112, 1121, 1211, 2111, relative frequency 4.

Class 3 comprises two different pairs of digits, as 2244, which has six possible permutations, frequency 6.

Class 4 comprises one pair of like digits, with two unlike numbers, which arrangement has 12 possible permutations, and therefore a relative frequency of 12.

Finally, class 5 comprises four unlike digits, with 24 possible permutations, and relative frequency 24.

TABLE 1.—*Data on throws of four dice. Products, type throws, and relative frequencies when all possibilites are exhausted*

[Mean or normal product, 150.06]

Products 150 and below						Products above 150					
Products	Type throws				Combined frequencies	Products	Type throws				Combined frequencies
1	1111				1	1296	6666				1
2	1112				4	1080	5666				4
3	1113				4	900	5566				6
4	1114	1122			10	864	4666				4
5	1115				4	750	5556				4
6	1116	1123			16	720	4566				12
8	1124	1222			16	648	3666				4
9	1133				6	625	5555				1
10	1125				12	600	4556				12
12	1126	1134	1223		36	576	4466				6
15	1153				12	540	3566				12
16	1144	1224	2222		19	500	4555				4
18	1136	1233			24	480	4456				12
20	1145	1225			24	450	3556				12
24	1146	1226	1234	2223	52	432	2666	3466			16
25	1155				6	400	4455				6
27	1333				4	384	4446				4
30	1156	1235			36	375	3555				4
32	1244	2224			16	360	2566	3456			36
36	1166	1236	1334	2233	48	324	3366				6
40	1245	2225			28	320	4445				4
45	1335				12	300	2556	3455			24
48	1246	1344	2226	2234	52	288	3446	2466			24
50	1255				12	270	3356				12
54	1336	2333			16	256	4444				1
60	1256	1345	2235		60	250	2555				4
64	1444	2244			10	240	3445	2456			36
72	1266	1346	2236	2334	60	225	3355				6
75	1355				12	216	1666	2366	3346		28
80	1445	2245			24	200	2455				12
81	3333				1	192	2446	3444			16
90	1356	2335			36	180	1566	2356	3345		48
96	1446	2246	2344		36	162	3336				4
100	1455	2255			18	160	2445				12
108	1366	2336	3334		28						
120	1456	2256	2345		60						
125	1555				4						
128	2444				4						
135	3335				4						
144	1466	2266	2346	3344	48						
150	1556	2355			24						

Number of cases 150 and below	41
Number of cases above 150	34
Total cases	75
Sum of frequencies 150 and below	899
Sum of frequencies above 150	397
Total frequencies	1,296

It will be noted that the gaps in distribution of products can never be filled, however large the number of throws of dice become. Similarly, notable gaps appear in the departures of even long records of rainfall. These considerations tend to support Mr. Moyer's assumption of likeness between rainfall and the casts of 4 or 5 dice scored by products.

Accuracy of the dice.—Theoretically, if any side of any or each of the four dice is a bit heavy, we may feel quite certain that in a large number of throws this heavy side will tend to go down too frequently, with a corresponding effect on the ultimate score.

The writer has found a very delicate test that shows any imperfections of this character. It consists in preparing a liquid solution in which the dice will almost but

not quite sink. For celluloid dice a solution of potassium iodide does the trick. The dice must be completely submerged, which requires that the lowermost layers of the solution be a little more dense than those above. The heavy side takes an undermost position, while the dice seems to poise suspended in the solution. Four high-

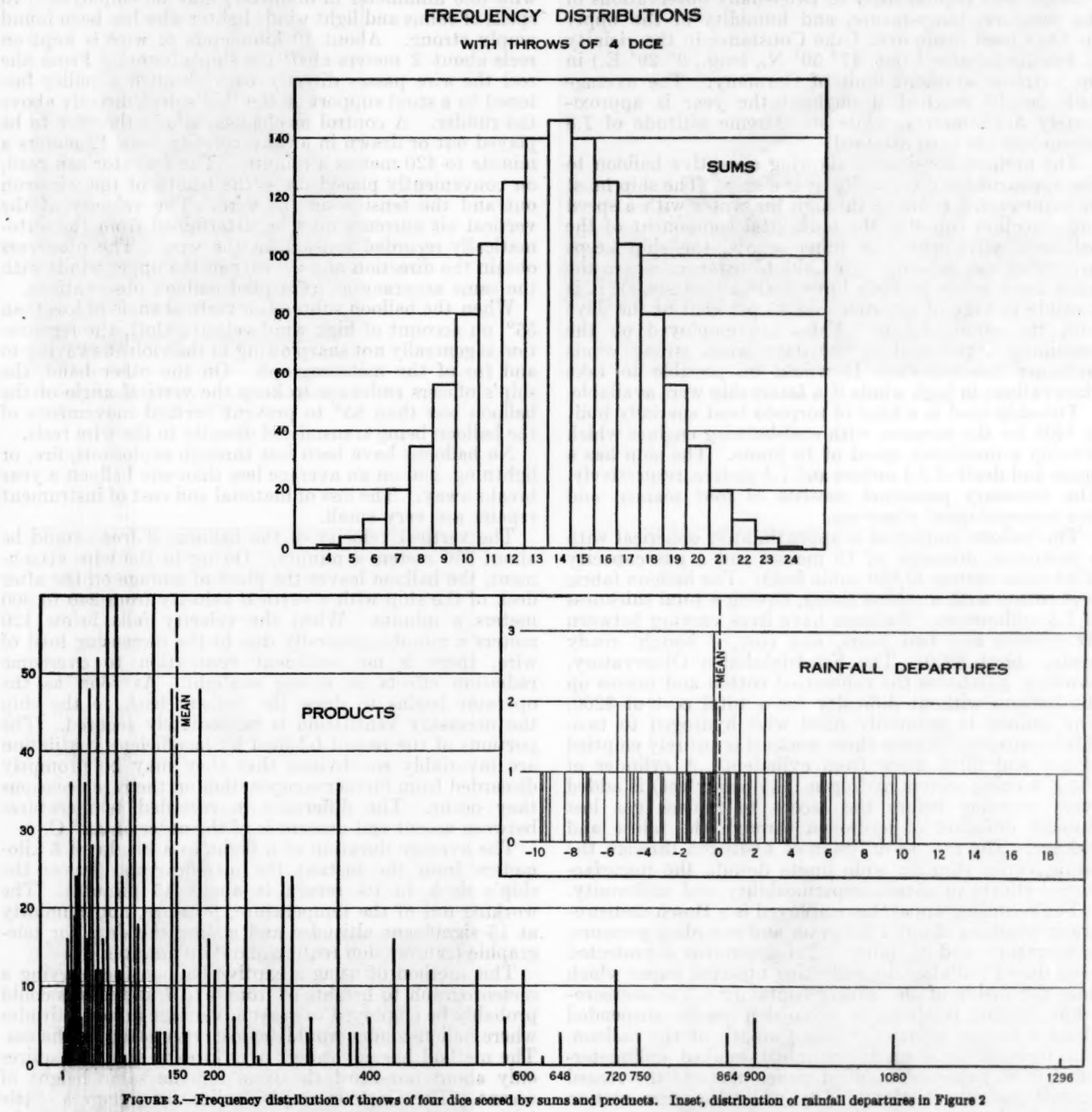


FIGURE 3.—Frequency distribution of throws of four dice scored by sums and products. Inset, distribution of rainfall departures in Figure 2

grade commercial dice, nearly 10 millimeters cube, invariably floated with the 4, 5, and 6 sides uppermost at some oblique angle. It is not difficult to understand why this should come about, because it is easy to see that an appreciable amount more celluloid is cut out in forming the small dimples for the dots on the 4, 5, and 6 faces than on the others, making them a trifle lighter than the other faces. The amount of the imperfection of balance could not be easily measured, and it is not known whether it is sufficient to influence the throws. I was prompted to develop and apply the test, however, when I noticed that after some 600 throws of these dice the normal ran appreciably higher than the theoretical normal, 150.06. The average of the first 500 throws was slightly over 157, which gives a decided upward trend to the plot of accumulated sums. No evidence of this effect appears in Mr. Moyer's data, and the discordance just mentioned may still be only a long-sustained dominance of high values by the vagaries of pure chance. The subject is a fascinating and alluring one to pursue.

AEROLOGICAL OBSERVATIONS MADE WITH A CAPTIVE BALLOON FROM A MOVING SHIP

By ANDREW THOMSON

[Drachenstation, Friedrichshafen. Germany, January 12, 1931]

Since 1908 regular daily or twice-daily observations of the pressure, temperature, and humidity of the upper air have been made over Lake Constance in the vicinity of Friedrichshafen [1] (lat. 47° 39′ N., long., 9° 29′ E.) in the extreme southern limit of Germany. The average daily height reached throughout the year is approximately 5 kilometers, while an extreme altitude of 7.8 kilometers has been attained.

The method consists in allowing a captive balloon to rise approximately vertically over a ship. The ship must be maneuvered to move through the water with a speed and direction equal to the horizontal component of the balloon's movement. In other words, the ship keeps pace with the balloon. On Lake Constance, where the wind force rarely exceeds force 5 (Beaufort scale), it is possible to take observations on 95 per cent of the days with the same balloon. Kites are employed on the remaining 5 per cent of the days when strong winds endanger the balloon. It would be possible to take observations in high winds if a faster ship were available.

The ship used is a kind of torpedo boat specially built in 1908 for the purpose, with coal-burning engines which develop a maximum speed of 16 knots. The ship has a beam and draft of 3.4 meters and 1.4 meters, respectively. The necessary personnel consists of four seamen and two meteorological observers.

The balloon employed is approximately spherical with a maximum diameter of 15 meters and a gas capacity of 80 cubic meters (2,850 cubic feet). The balloon fabric is of cotton with a rubber lining, having a total thickness of 1.5 millimeters. Balloons have lives varying between six months and two years, and cost, if bought ready made, about $500. The Friedrichshafen Observatory, however, purchases the rubberized cotton and makes up the balloon without difficulty for a total cost of $200. The balloon is ordinarily filled with hydrogen to two-thirds capacity. Every three weeks it is entirely emptied of gas and filled anew from cylinders. A cylinder of about 4 cubic meters hydrogen (145 cubic feet) is added every morning before the ascent to replace gas lost through diffusion of hydrogen through the fabric and leakage. The rate of diffusion of hydrogen through the fabric varies through wide limits despite the manufacturers' efforts to obtain impermeability and uniformity.

The recording apparatus employed is a Bosch meteorograph weighing about 1 kilogram and recording pressure, temperature, and humidity. The apparatus is protected from direct radiation by reflecting nickeled paper which lines the inside of the wicker container. The meteorograph basket is slung in a wooden cradle suspended about 8 meters below the filling mouth of the balloon. The registration is made on lightly-smoked millimeter-ruled oiled paper. The oiled paper protects the record against the effects of humidity while the cross-section ruling facilitates rapid reduction of observations.

Steel wire 0.7 millimeter in diameter with a breaking strain of 90 kilograms is used for attaching the balloon for the first 3,000 meters of its ascent. Subsequently finer wire (0.6 millimeter in diameter) may be employed. In spells of calms and light winds lighter wire has been found amply strong. About 10 kilometers of wire is kept on reels about 2 meters abaft the ship's funnel. From the reel the wire passes directly back through a pulley fastened to a stout support on the ship's deck directly above the rudder. A control mechanism allows the wire to be played out or drawn in at any velocity from 12 meters a minute to 420 meters a minute. The operator can read, on conveniently placed dials, the length of the wire run out and the tension on the wire. The velocity of the vertical air currents may be determined from the automatically recorded tension on the wire. The observers obtain the direction and velocity of the upper winds with the same accuracy as from pilot-balloon observations.

When the balloon subtends a vertical angle of less than 55°, on account of high wind velocity aloft, the registration is generally not sharp owing to the violent swaying to and fro of the meteorograph. On the other hand, the ship's officers endeavor to keep the vertical angle of the balloon less than 85° to prevent vertical movements of the balloon being transmitted directly to the wire reels.

No balloons have been lost through explosions, fire, or lightning, and on an average less than one balloon a year breaks away. The loss of material and cost of instrument repairs are very small.

The vertical velocity of the balloon, if free, would be about 330 meters a minute. Owing to the wire attachment, the balloon leaves the place of storage on the after deck of the ship with a vertical velocity from 240 to 300 meters a minute. When the velocity falls below 120 meters a minute, generally due to the increasing load of wire, there is not sufficient ventilation to overcome radiation effects in strong sunlight. As soon as the operator begins to draw the balloon back to the ship the necessary ventilation is immediately secured. The portions of the record falsified by insufficient ventilation are invariably so obvious that they may be promptly discarded from further computation on the rare occasions they occur. The difference in recorded temperatures between ascent and descent is of the order of 0.2° C.

The average duration of a flight to a height of 5 kilometers from the instant the meteorograph leaves the ship's deck to its return is about 45 minutes. The working out of the temperature, pressure, and humidity at 15 significant altitudes and coding the data for telegraphic transmission require about 40 minutes.

This method of using a captive balloon for carrying a meteorograph to heights of from 4 to 7 kilometers could probably be employed to great advantage in low latitudes where ballon-sondes would be lost very often in the sea. The method has advantage over kites in that it requires only about one-third the time for the same height of ascent. The meteorograph ordinarily receives little jolting so that much more sensitive instruments may be employed with a balloon than with a kite. As the records for both ascent and descent are equally distinct two independent determinations of temperature and humidity, taken within a short space of time, may be made at any desired altitude. This provides an invaluable check on computations and a lag and other instrumental defects.

A captive balloon can be sent up in foggy and hazy days when airplane flights would be dangerous, especially

[1] Count Zeppelin, in the course of his airship investigations, established, about 1900, the meteorological station at Friedrichshafen. Dr. H. Hergesell, collaborating with Count Zeppelin from 1900 to 1908, made use of both captive balloons and captive kites, fastened to a moving ship for taking upper-air observations. Dr. E. Kleinschmidt, who was appointed director of the Drachenstation in 1908, introduced during his term of office certain practical details in the captive-balloon method here described.

(To face p. 494)

FIGURE 1.—Balloon inflated to hold about 2,000 cubic feet of hydrogen

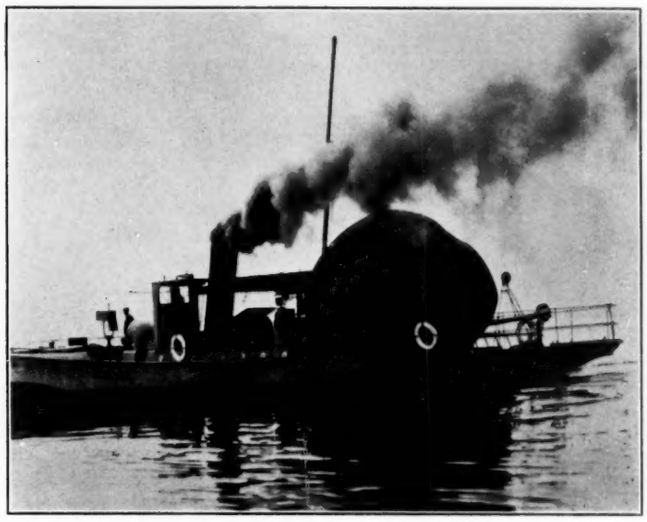


FIGURE 2.—Balloon stowed on after deck of torpedo boat *Gna*

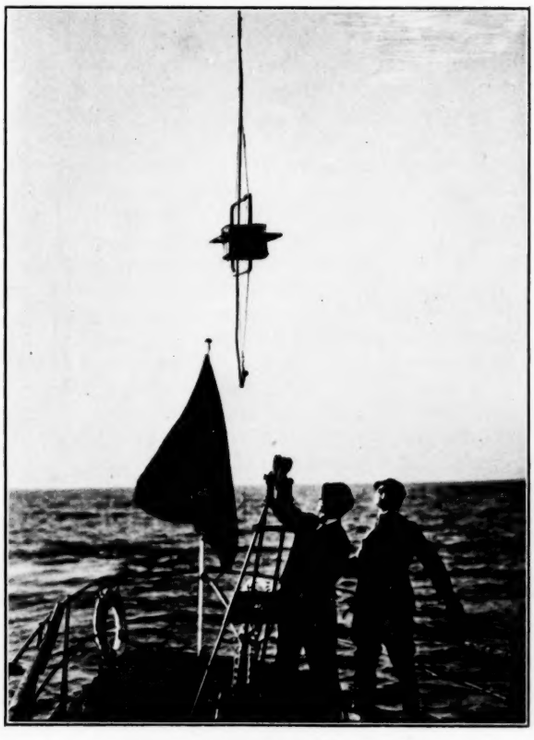


FIGURE 3.—Balloon just after leaving ship

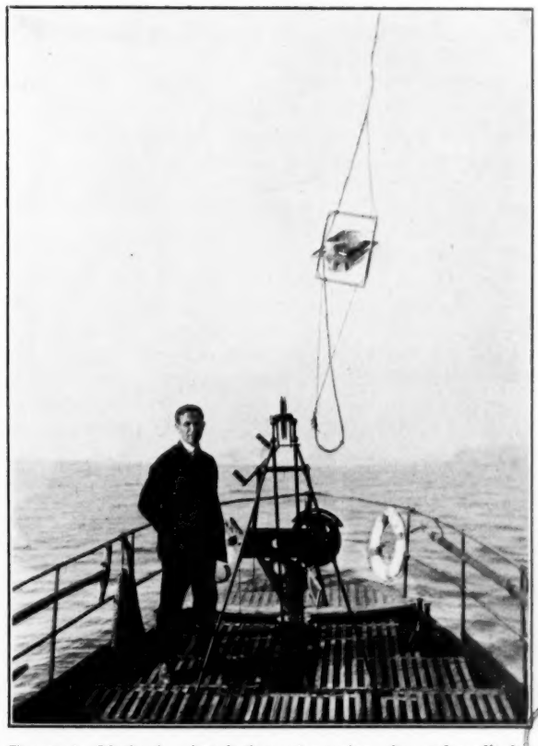


FIGURE 4.—Mechanism for playing out mooring wire, and cradle for meteorograph

UNIV. OF MICH.

at a coastal station. The method can not be used successfully in regions with high winds or where harbors are icebound for a considerable portion of the year. However, meteorologists, with the cooperation of port or naval authorities might obtain by the captive-balloon method here described, extremely valuable data concerning the temperature and humidity of the upper air in tropic and tradewind regions. Only very meager aerological observations are now available from this vast area.

The writer is greatly indebted to Dr. W. Peppler, director Drachenstation, Friedrichshafen, for opportunity to take part in the daily program of balloon ascents over Lake Constance and for many details of the method given in this article.

No detailed description of the technique and apparatus employed in taking aerological observations with a captive balloon, moored to a moving ship, has yet been published.

Brief notices regarding the method have appeared in Beiträge zur Physik der freien Atmos., Band I, page 1, et seq., and in the MONTHLY WEATHER REVIEW for September, 1908, volume 36, page 284, by E. Kleinschmidt (translation by C. F. Talman). Doctor Kleinschmidt has given a fuller account in the Deutsches Met. Jahrbuch, 1908. Capt. G. Hugo presented a report on the method to the Premier Congrès International de la Sécurité aérienne in Paris, 1930, which will appear in the Proceedings of the Congress.

METEOROLOGY AND SEASONAL WEATHER FORECASTING: ANNUAL PROGRESS REPORT OF THE SCRIPPS INSTITUTION OF OCEANOGRAPHY

By GEO. F. MCEWEN, Physical Oceanographer, and A. F. GORTON, Associate in Meteorology

[La Jolla, Calif., January 1931]

Our efforts during the past year were devoted to a further study of the relation between seasonal rainfall in California and quarterly values of temperatures and pressures in various parts of the world, and to an analysis of cycles in rainfall and run-off by statistical methods, in particular, Streiff's method of successive integration. Correlation coefficients higher than 60 per cent have been established for several indices covering the period 1916–1930, these including La Jolla water temperatures during the upwelling period and July to September, also, Tokyo air temperatures versus Hetch-Hetchy district rainfall and Huntington Lake inflow. The Tokyo index prior to 1916, shows a lower degree of correlation. Other indices, such as August to October rainfall in southern Alaska (with respect to following winter's rain in California) proved disappointing.

Air temperatures, in general, are poor indicators of California precipitation. Groissmayr's correlation between summer conditions in India and following winter temperature departures in central Canada was found to be without much bearing on rainfall in this state, neither was there much connection between winter temperatures in Canada and California. There is some evidence that Scripps Pier temperatures during the upwelling period indicate the trend of temperature departures in southern California during the fall.

A composite index has been worked out which is found to fit rainfall departures in southern California much more exactly than the original McEwen index. This takes into account the rapidity with which the temperature approaches a maximum and the time of occurrence of the maximum temperature, as well as the actual magnitude of the latter. The same procedure applied to the Pacific Grove temperatures gives a good indication of rainfall departures in the north coast region.

As to cycles, the important ones are in order of length, the secular cycle of 50 to 60 years, the Brückner cycle of 22 to 26 years, the double-Wolf cycle of 5 to 6 years, and the Clough cycle of 2 to 3 years. The 5 to 6 year cycle seems to be the most important for forecasting purposes. The Brückner cycle is prominent in the rainfall of Southern California and is found in records of lake levels (Great Salt Lake and the Great Lakes). The next maximum in the 5 to 6 year cycle will come probably in 1933, and a rise in the Brückner cycle now under way, will bring rainfall to a maximum around 1938–40.

The annual forecast was published October 15, 1929, in various newspapers of the State and was distributed through the Associated Press to newspapers outside the State; the same forecast appeared in the Bulletin of the American Meteorological Society and the California Citrograph. A paper prepared by Doctor Gorton on the results of the last two years' work was published in the Electrical West (September, 1930) and much the same material was presented at a meeting of the American Institute of Electrical Engineers in Portland, Oreg., September 5 (published in Journal, A. I. E. E. December, 1930). Doctor McEwen prepared a paper entitled "Our Rainfall: How is it Formed and What Becomes of It?" (published in the Scientific Monthly, November, 1930).

During the coming year we plan to devote our time to the following studies:

a. A further analysis of factors affecting seasonal storm tracks.

b. Surface temperatures off the California coast by 1° squares between latitude 30° and 40°, for period 1900–1930. Data from United States Weather Bureau.

c. Gulf Stream temperatures and their relation to seasonal rainfall in California. (Data by Brooks.)

d. Further study of cycles in rainfall, run-off, sun spots, tree rings, etc.

THE WEATHER OF 1930 IN THE UNITED STATES

By ALFRED J. HENRY

The outstanding feature of the weather of 1930 was the great drought and its associated high temperatures during July and August. This phenomenon has been rather fully treated in the issues of this REVIEW for September and October, 1930, and will not be again considered in detail at this time; we reproduce, however, tables and charts that show for the year in question the departures of temperature and precipitation for the year as a whole, in the same manner as followed in previous years. Tables 1 and 2 show, respectively, the monthly departure of temperature and precipitation for each month according to the geographic districts into which the United States is divided for the purpose of publishing statistics of the weather.

TABLE 1.—*Monthly and annual temperature departures, 1930*

District	January	February	March	April	May	June	July	August	September	October	November	December	Average
New England	+2.8	+3.5	+1.9	−0.4	+2.2	+4.2	+0.4	−0.1	+4.3	−0.2	+2.5	+0.8	+1.8
Middle Atlantic	+2.5	+6.0	+1.3	−0.7	+2.6	+2.0	+1.5	+0.2	+5.2	−1.8	+1.0	−1.1	+1.6
South Atlantic	+2.7	+5.1	−2.3	+1.7	+2.1	−1.2	+2.3	−0.8	+4.2	−2.7	−1.6	−4.2	+0.4
Florida Peninsula	+3.8	+2.9	−1.7	+0.7	+1.5	−1.5	+1.1	+0.5	+1.6	−0.8	−1.2	−3.7	+0.3
East Gulf	−0.5	+4.7	−3.6	+2.2	+1.1	−0.8	+2.3	+0.1	+1.7	−2.3	−0.3	−3.7	+0.1
West Gulf	−8.2	+6.8	−3.3	+3.6	−0.7	−0.5	+1.8	+2.1	+1.7	−1.0	−0.4	−2.1	0.0
Ohio Valley and Tennessee	−0.6	+8.2	−1.6	+2.9	+1.0	+0.1	+2.8	+0.6	+2.8	−2.5	+0.7	−2.4	+1.0
Lower Lakes	0.0	+6.8	0.0	−0.1	+1.7	+2.3	+0.4	+0.7	+2.6	−1.5	+3.4	+0.2	+1.4
Upper Lakes	−3.4	+6.8	+1.0	+1.1	+2.1	+2.3	+0.8	+3.3	+1.5	−1.4	+3.3	+1.0	+1.5
North Dakota	−6.8	+14.2	+4.0	+7.1	−2.6	+0.9	+4.6	+5.0	−0.1	−2.8	+2.6	+8.5	+2.9
Upper Mississippi Valley	−6.7	+11.7	+1.5	+3.6	+0.5	+0.3	+3.0	+3.0	+2.2	−1.2	+3.7	+1.7	+1.9
Missouri Valley	−8.9	+15.1	+1.4	+5.0	−0.9	−0.3	+5.2	+3.3	+1.8	−1.2	+3.3	+3.8	+2.3
Northern Slope	−13.2	+12.6	+0.1	+7.5	−0.9	+0.5	+3.9	+3.4	+1.0	−2.2	+0.7	+3.3	+1.4
Middle Slope	−11.5	+12.4	−1.6	+6.2	−1.2	+1.2	+2.6	+2.3	+2.1	−1.4	+2.2	+0.4	+1.1
Southern Slope	−8.8	+8.6	−3.0	+5.4	−0.6	+0.1	+1.1	+3.0	+4.0	−0.6	−0.1	−2.0	+0.6
Southern Plateau	−1.7	+5.2	−0.4	+5.0	−3.8	+1.9	+0.5	+0.6	−0.1	+0.1	−0.2	−1.2	+0.5
Middle Plateau	−6.1	+4.3	+1.3	+5.1	−2.4	+2.0	+2.3	+0.6	−0.2	−1.2	−3.3	−5.0	−0.2
Northern Plateau	−13.2	+6.7	+1.8	+5.2	−0.9	−0.7	+3.2	+3.5	+1.8	−1.8	−3.1	−5.6	−0.3
North Pacific	−8.1	+3.5	+2.5	+3.6	−1.1	−0.6	+0.2	+2.6	+1.0	−0.3	−0.3	+0.7	+0.3
Middle Pacific	−1.2	+3.7	+2.6	+2.8	−2.1	+1.1	−0.2	+0.8	−1.2	+0.5	+0.8	−0.1	+0.6
South Pacific	+1.0	+3.8	+2.8	+3.6	−1.7	+0.9	+1.5	+0.8	−1.7	+1.7	+3.4	+1.7	+1.5
United States	−4.1	+7.3	+0.2	+3.4	−0.2	+0.7	+2.0	+1.7	+1.7	−1.2	+0.8	−0.4	[1] +1.0

[1] Annual departure.

TABLE 2.—*Precipitation departures, monthly and annual, 1930*

District	January	February	March	April	May	June	July	August	September	October	November	December	Sum
New England	−0.7	−0.9	+0.3	−1.5	+0.4	−0.4	−0.5	−1.5	−2.1	−0.2	+0.5	−1.0	[1] −7.6
Middle Atlantic	−0.5	−1.1	−1.3	−0.9	−0.9	+0.3	−1.4	−2.5	−1.3	−1.7	−0.5	−1.0	−12.8
South Atlantic	−0.1	−2.7	0.0	−0.8	−1.3	+0.4	−1.0	−3.6	+0.3	−1.6	+1.0	+0.1	−9.3
Florida Peninsula	+0.6	+1.4	+3.8	+2.6	+1.8	+9.7	−2.3	−0.9	−3.4	−1.2	−1.0	+2.1	+13.2
East Gulf	+0.2	−2.6	+0.8	−2.2	+0.8	−2.8	−1.7	−1.9	+2.5	−0.3	+4.4	−2.0	[1] −4.8
West Gulf	+0.8	−0.2	−0.9	−2.1	+3.1	−2.2	−2.1	−1.4	−0.6	+3.0	+0.1	−0.4	[1] −2.9
Ohio Valley and Tennessee	+1.0	−0.3	−1.3	−1.8	−1.1	−1.9	−2.2	−1.4	−0.2	−1.4	−1.1	−1.7	−13.4
Lower Lakes	+1.5	−0.9	+0.6	−0.2	−0.7	+0.5	−1.5	−1.7	−0.4	−1.0	−1.2	−1.5	−6.5
Upper Lakes	+0.1	0.0	−0.7	−0.6	−0.7	0.0	−1.5	−2.1	−1.0	−0.8	−0.9	−1.1	−9.3
North Dakota	−0.3	+0.8	−0.7	0.0	−0.1	−1.4	−1.5	−0.3	−0.6	+0.4	+0.6	−0.4	−3.5
Upper Mississippi Valley	+1.2	+0.1	−1.2	−0.8	−1.2	+1.6	−2.3	−1.9	−0.9	−0.4	0.0	−1.0	−6.8
Missouri Valley	+0.7	−0.4	−1.2	+0.1	−0.2	−0.9	−2.5	−0.3	−0.7	+0.5	+1.0	−0.6	[1] −4.5
Northern Slope	−0.2	−0.2	−0.2	−0.3	+0.1	−0.8	−0.6	+0.8	−0.1	+1.0	+0.2	−0.6	[1] −0.9
Middle Slope	+0.5	−0.3	−1.3	−0.3	+0.9	+0.1	−1.2	−0.6	−0.2	+0.8	+0.9	+0.3	−0.4
Southern Slope	−0.3	−0.7	+0.3	−0.1	−0.6	0.0	−1.3	−1.2	−1.1	+4.0	0.0	+0.1	[1] −0.9
Southern Plateau	0.0	−0.1	+0.3	−0.1	+0.3	−0.1	+0.1	−0.3	−0.3	−0.2	0.0	−0.6	[1] −1.0
Middle Plateau	+0.7	−0.2	−0.6	−0.2	+0.5	−0.2	0.0	+0.5	+0.4	−0.1	+0.3	−0.8	+0.3
Northern Plateau	−0.4	+0.1	−0.4	+0.1	+0.3	−0.4	−0.4	+0.6	+0.2	−0.2	−0.5	−0.9	−1.9
North Pacific	−2.8	+0.4	−1.4	−0.3	0.0	−0.3	−0.6	−0.5	−0.3	0.0	−3.0	−3.8	−12.6
Middle Pacific	−0.2	−1.0	−0.4	−0.6	−0.1	−0.3	0.0	0.0	−0.2	−0.6	−1.2	−2.9	−7.5
South Pacific	+1.5	−1.2	+0.8	−0.4	+0.6	−0.1	0.0	0.0	−0.1	−0.4	+0.3	−2.0	−1.0
United States	+0.2	−0.5	−0.2	−0.5	+0.1	0.0	−1.2	−1.0	−0.5	0.0	0.0	−0.9	−4.5

[1] The deficit in the 1894 drought was somewhat greater.

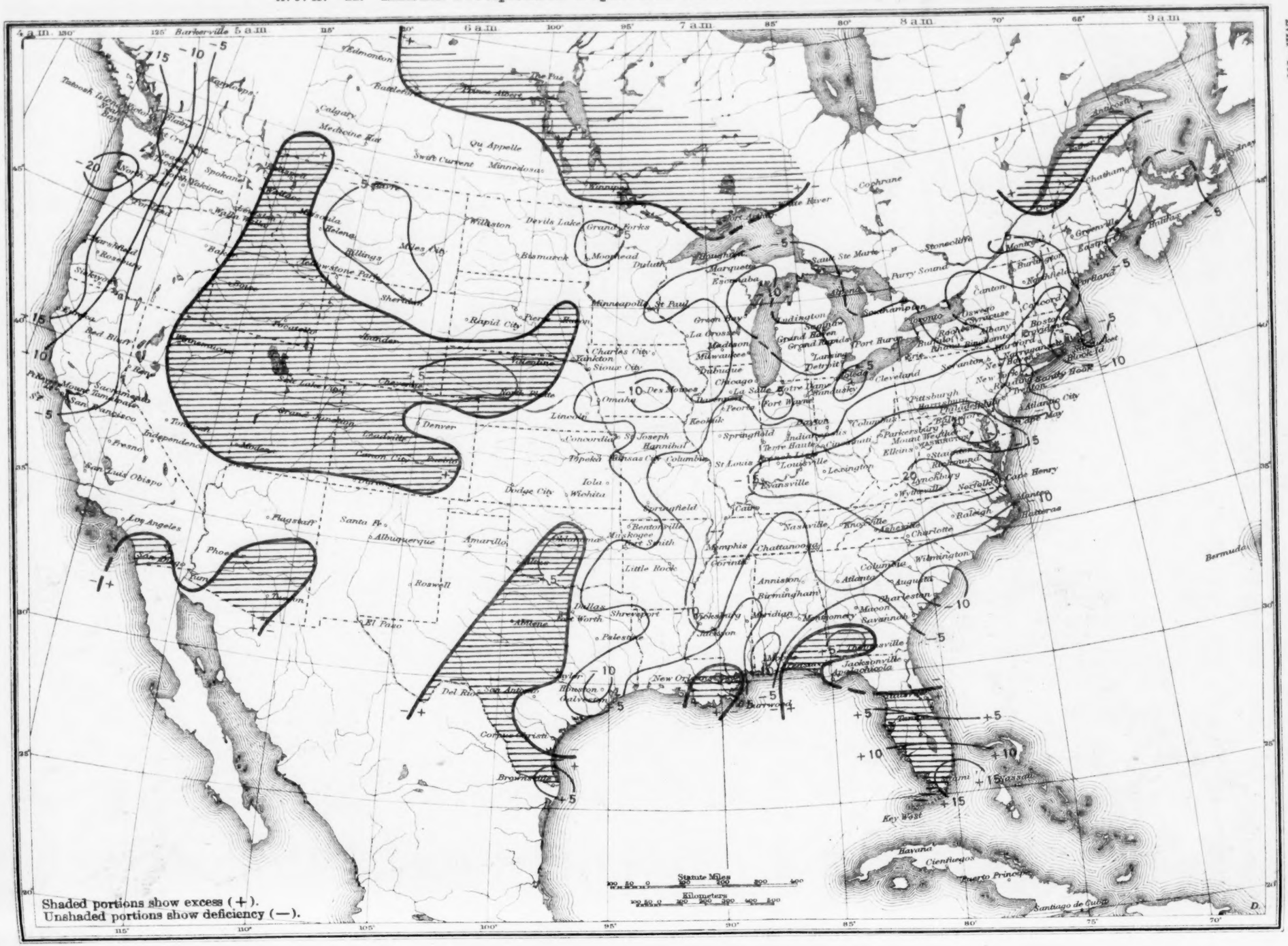
Precipitation was greater than normal in the peninsula of Florida, in a narrow belt along the immediate Gulf Coast, except from western Louisiana to near the mouth of the Rio Grande, in parts of west Texas and Oklahoma, and over a rather large area in the Great Basin and eastward over Wyoming to western South Dakota; also in southeastern Arizona.

Precipitation was below normal elsewhere in the United States. The departures by State boundaries show the following: Maryland without 56 per cent of normal, followed by West Virginia, 59; Virginia, 60; Kentucky, 61; Delaware, 65; and Pennsylvania, 68 per cent.

It should be remembered that the two charts are based on telegraphic reports from about 200 Weather Bureau stations and that a larger number and better distribution of the reporting stations would probably show a somewhat different result, especially as to the areas of positive and negative departures.

Shaded portions show excess (+).
Unshaded portions show deficiency (—).
Statute Miles
Kilometers

II. Annual Precipitation Departures (inches) in the United States, 1930



PRELIMINARY STATEMENT OF TORNADOES IN THE UNITED STATES DURING 1930

By HERBERT C. HUNTER

[Weather Bureau, Washington, January 28, 1931]

In advance of the final study of the windstorms of 1930, which is expected to be finished during the summer of 1931, this preliminary statement, compiled from the material thus far assembled through the assistance of many, especially the several section directors, almost all of which was used in the monthly tables of "Severe local storms," is presented:

TORNADOES AND PROBABLE TORNADOES

	January	February	March	April	May	June	July	August	September	October	November	December	Year
Number	0	0	8	5	82	36	13	7	17	2	17	0	187
Deaths	----	----	4	0	114	8	0	0	5	3	32	----	166
Damage [1]	----	----	678	48	6,865	1,969	113	85	654	50	642	----	11,104

TORNADIC WINDS AND POSSIBLE TORNADOES [2]

Number	0	2	1	0	3	2	0	0	0	0	2	0	10
Deaths	----	0	0	----	1	0	----	----	----	----	0	----	1
Damage [1]	----	52	6	----	250	13	----	----	----	----	6	----	327

[1] In thousands of dollars.
[2] Several of these, in the final study, will probably be classed as not tornadoes.

In reviewing the 1930 material, from which this tabular statement was prepared, and the final studies of the years just preceding, it was noted that at the end of 1930 a period of 39 months had gone without any one tornado in the United States causing property losses to the amount of $2,500,000, or the loss of as many as 50 lives. However, on a few occasions a group of tornadoes visiting one State during one day had together caused more than 50 fatalities. In the aggregate, the tornadoes of these 39 months resulted in losses of 539 lives, according to the best information at hand, and about $36,000,000 of property.

By contrast, the tornado record of the slightly longer period of 45 months next preceding may be summarized; that is, from the beginning of January, 1924, to the end of September, 1927. Within this 45-month period there occurred six tornadoes causing losses of more than 50 lives each, the counts actually ranging from 67 to 689, while three of the six caused property losses exceeding $10,000,000 each. The total figures of losses from the tornadoes of these 45 months were 1,848 lives and almost $97,000,000 of property.

NOTES, ABSTRACTS, AND REVIEWS

Dr. George C. Simpson on Thunder and Lightning [1]—*Abstracted and condensed by A. J. Henry.*—Doctor Simpson, in his opening paragraph, points out that while it is nearly 200 years since Dalibard and Franklin showed conclusively that lightning is an electric discharge there is as yet no unanimity of opinion as to the mechanism by which the electricity is generated in the thunderstorm. He believes that at present there are but two theories that are seriously considered, viz, those of C. T. R. Wilson [2] based on electrical induction, and the one based on the breaking of raindrops.[3] The latter theory starts from the observation that when a drop of water breaks up in the air there is a separation of electricity, the water becoming positively charged and the air negatively charged.

In all thunderstorms there are violent ascending air currents which hold up large amounts of water in the form of rain drops. These rain drops are constantly breaking and reforming and the air which streams past them becomes negatively charged. In this way there is a large separation of electricity, the cloud as a whole becoming more and more charged with negative electricity, while the water held in suspension in the ascending currents becomes very highly positively charged.

For a long time it was considered that a cloud is more or less a good conductor of electricity. It is now known, according to Doctor Simpson, that this is not the case, and that when electricity is separated into two parts of a cloud it remains as a volume charge. If the process which separates the electricity continues the charge goes on accumulating until the electrical field becomes so intense that the electrical resistance of the air breaks down and a lightning discharge passes.

When air is subjected to an electrical stress little happens until a certain field strength is reached when "electrical breakdown" occurs.

The breakdown is due to the splitting up of neutral air molecules into ions and electrons. Now, ions and electrons can move under an electrical field, and therefore when the air has broken down an electrical current can pass, the electricity being conveyed by the moving ions and electrons, especially the electrons which move several hundred times faster than the ions.

In a thunder cloud in which active separation of electricity is taking place the field increases until the electrical resistance of the air breaks down, generally at some point well within the cloud. At first the region of breakdown is very local but the rent, having once been started, rapidly extends in the form of a narrow channel; but the most important characteristic of such a rent is that it can only extend in one direction, that is, away from the seat of the positive electricity. As the channel extends, it tends to branch and each branch becomes a new rent. Thus when we see a lightning discharge we can tell from the branching which way it has extended and where the positive electricity is situated.

The rate at which a lightning channel grows is usually very great. It has not been possible to measure the rate of growth of a natural lightning channel; but from experiments made in the laboratory we know it can be as fast as one-tenth of the velocity of light. On the other hand, as I shall show later, the channel grows relatively slow. The light associated with a lightning flash is due to the recombination of electron and ions within the ionized channel. The first discharge which opens the channel leaves the air within the channel very highly ionized and so long as the channel remains ionized an electrical current can pass along it.

The current itself renews the ionization so that the channel continues to glow so long as a current passes. Recombination however, is relatively a slow process and the channel remains ionized for some appreciable time after the visible discharge has ceased.

The numerous different kinds of lightning are due to the different forms which the channel can take. Many

[1] The thirty-second Robert Boyle lecture, delivered before the Oxford Junior Scientific Club, June 7, 1930.
[2] Journal Franklin Institute, 208, p. 1, 1929.
[3] G. C. Simpson; Proceedings Roy. Soc. A; 114, p. 376, 1927.

attempts have been made to classify lightning discharges according to their forms; but as there are no hard and fast distinctions between the different forms the attempt has not been very successful. There are, however, several quite characteristic forms assumed by lightning which I propose to consider and explain them so far as the explanation is known.

Branched discharges between the earth and the clouds, by far the most common form of lightning discharge, is one with clearly defined branches. When the branches are directed away from the cloud it indicates that the cloud was positively charged. In other cases, but much more rarely, the branches are directed toward the cloud thus showing that the cloud was negatively charged. There is an important difference between two such discharges. When the positive charge is in the cloud each channel which reaches the ground only carries part of the electricity which left the cloud, for part of the charge is used up in the channel itself and a large portion passes through other branches, some of which never reach the ground at all. On the other hand when the cloud is negatively charged, the discharge starts on the ground and it is only later when the channel has grown upward that branching takes place. Thus all the electricity associated with a discharge from the ground to a negative cloud passes through a single channel when near the ground; therefore an object struck by such a discharge is more seriously damaged than an object struck by the attenuated end of a discharge from a positively charged cloud.

Doctor Simpson illustrates by half tones and discusses the different forms of lightning as enumerated below:

(1) Discharges between clouds; (2) stream discharges; (3) meandering flashes; (4) intermittent discharges; (5) pearl necklace lightning; (6) rocket lightning; (7) sheet lightning; and (8) ball lightning. In regard to the last named Doctor Simpson admits that he can not see even the beginning of an explanation and is unwilling to add another guess to the many that already have been made.

The above named forms are more or less familiar to readers of the REVIEW with the exception of rocket lightning. I therefore quote Doctor Simpson's description of this phenomenon:

> Rocket lightning: In the forms of lightning so far discussed the channel has been formed in such a short space of time that its formation could not be observed. The long duration of the flashes, especially with intermittent lightning, has been due to the discharge occupying the channel for a long period—sometimes as long as a few seconds—after it has been formed. There is, however, a type of lightning discharge which starts in a cloud and then progresses so slowly across the sky that the eye can follow its progress with ease, in the same way that the path of a rocket can be seen. I saw this phenomenon in Belgaum, India, in the year 1907. There was a thunderstorm in the distance, the cumulus cloud of which stood up sharp against the sky. From the lower part of the cloud a series of discharges took place, the discharges moving quite slowly in a horizontal direction to some considerable distance from the cloud. The effect was as though coiled up ribbons were being thrown out of the cloud which unrolled as they moved to the right. This slow-moving lightning has very appropriately received the name of rocket lightning.

E. M. Keyser on An Inland Empire Long-period Rainfall Riddle.—In an article entitled "An Inland Empire Long-Period Rainfall Riddle" in the July number of the MONTHLY WEATHER REVIEW, E. M. Keyser reviews two papers in evidence of a decided lack of synchronism between the long-period rainfall distribution in Spokane County, Wash., and the adjoining county of Bonner, Idaho.

O. W. Freeman, in one paper, on the evidence of the exposure of pine stumps in Silver and Granite Lakes, Wash., as the waters have receded in recent years, concludes that a past dry period of at least a century accounts for the presence of trees in what is now a lake, and that a wetter period, beginning two or three decades ago, caused the lake levels to rise, submerge the trees at their bases, and kill them.

Robert Marshall, in studying rates of growth in trees by stem analysis near Priest River, Idaho, finds evidence in support of a recent dry period coincident with the high lake level period in Granite and Silver Lakes and a previous wet period at the time when the trees whose stumps are exposed were growing.

It is noteworthy that Granite and Silver Lakes lie in the dry margin of a forested region. Timber in the vicinity is scarce, and just a few miles to the westward the country becomes definitely too dry for tree growth. It seems unlikely, therefore, that trees would thrive in the vicinity if it were considerably dryer than at present, unless locally abundant soil moisture as might be found in a seepage slope were present. In view of this, the trees whose stumps now appear in Silver and Granite Lakes are as good evidence in support of a past period of abundant moisture as they are in support of a dry period. Moreover, if their presence is the result of moister rather than dryer condition in the past, it is evidence of a rainfall cycle synchronous with that of Bonner County, Idaho, which would be expected from the proximity of the two localities. It is not unlikely, as Mr. Keyser suggested, that another explanation than increasing rainfall can be found for the submerging of the trees by the waters of Silver and Granite Lakes.—*Carleton P. Barnes.*

George C. Simpson on the Climate During the Pleistocene Period.[4]—Doctor Simpson, present director of the British Meteorological Office, continuing his studies of the climates of past geological ages, now presents a discussion of Pleistocene climate in an address given on June 16, 1930.

More than a score of methods of accounting for ice ages have appeared. The problem has been discussed by geologists, meteorologists, biologists, and others who may or may not come within those groups. No method has been universally accepted; therefore a fresh discussion, especially by one who has made a special study of the subject, is welcome.

Lack of space prevents us from presenting more than the summary of conclusions in the author's own words; these are not laid down with an air of finality, in fact the author admits that the record is not always clear and that inferences are at times difficult.—*A. J. H.*

SUMMARY

It is assumed that the glaciation of northern Europe during the great ice age was due to a shift of the pole associated with appreciable variations of solar radiation.

The shift of the pole brought Europe into sufficiently high latitudes to permit of the formation of an ice sheet; but the large variations of climate during the ice age, as shown by the interglacial epochs, were due to the oscillations of the solar energy.

If two complete cycles of solar radiation occurred during the Pleistocene period, it is possible to account for four advances of the ice in the Alps as demonstrated by Penck and Brückner, but the interglacial epochs were not all warm. The Günz-Mindel and the Riss-Würm interglacial epochs occurred at the maximum of the solar radiation and were, therefore, warm interglacial epochs; but the Mindel-Riss interglacial epoch occurred at a minimum of solar radiation and was, therefore, a cold interglacial epoch.

At a maximum of solar radiation—that is, during a warm interglacial epoch—the climate of northwest Europe was warm and very wet, with a relatively small annual variation of temperature. As the intensity of solar radiation decreased, the mean temperature fell and the annual variation of temperature increased. At the same time the amount of precipitation decreased. The fall of temperature occurred sufficiently rapidly compared with the decrease in precipitation to cause the glaciers of the Alps to advance and for

[4] Reprint from Proc. Roy. Soc. Ddinburgh, Vol. L, Part III, No. 21.

an ice sheet to form over Scandinavia. As the solar radiation still further decreased, the lack of precipitation caused the glaciers of the Alps to retreat. At the minimum of solar radiation there was a cold interglacial epoch with low mean temperature, a large annual variation of temperature, and very low precipitation; in fact, a truly continental climate.

With these changes of climate went a corresponding change in the flora, the sequence being park land, forest, tundra, grass with sparse trees, and steppe. In this way it has been found possible to determine a sequence of climates and of fauna and flora for the whole Pleistocene period, which is supported by the geological and archæological evidence available. In particular it is possible to arrange the sequence of human culture, the geological strata of East Anglia, and the history of the ice in the Alps into the scheme of climate change.

The two maxima of solar radiation were accompanied by increased precipitation in all parts of the world, so accounting for the two pluvial periods which are known to have occurred during the Pleistocene period.

K. Knoch and E. Reichel[5] *on the Distribution and Annual March of Precipitation in the Alps.*—This work is the first attempt to summarize all the monographs and separated data published in four different countries, in three different languages. In the first chapter the authors discuss the origin of the data used.

The second chapter is a discussion of the distribution of the precipitation. The first problem to be solved was the drawing of the different maps. The greatest possible accuracy was obtained, but even in spite of the careful work the authors do not claim to present the actual, accurate amount of precipitation, but to give a basis for comparison regard to the precipitation and the height of the Alps.

There are five distinct regions (1) the dry region of the southern French Alps, relatively low, and in the Mediterranean climatic influence; (2) wet, west and north front Alps, first condensation of the westerly winds; (3) wet region of south and east Switzerland, warm south foehn and the uplift of the warm air masses by the influx of northern cold air; (4) the rainy region of the southeastern Alps, the nearness of the Adriatic Sea; (5) the dry regions of southwestern Switzerland and of the zone of the central Alps, rain shadow.

The dryness of the valleys is due to rain shadow affect. Interesting phenomenon is that of the rain beam. Every valley opens into a region of more precipitation, thus the isohyets of lesser precipitation form closed line on the valley bottoms. The amount of precipitation in the valleys depends entirely upon the direction of the valley in regard to the winds, and every change in direction results in a change in precipitation.

As to the theoretical maximum zone of precipitation lower than the maximum height of the mountains, the authors maintain that this does not exist in the Alps.

The third chapter deals with the yearly march of precipitation. The chief types are (1) summer rain, July maximum; (2) transition types; (3) equinox type, May and October maximum; (4) French type, October maximum; (5) highland types, irregular maximum.

In the fourth chapter the authors briefly discuss the variability of the means and the absolute variability of precipitation.

The last 30 pages are devoted to tables containing the mean annual precipitation values of all the stations available and their heights above sea level, monthly values and the monthly proportions of the yearly total, extreme monthly and yearly values, comparisions of the 10 and 20 years means with that of 40 (30) years.

There are four supplements, one precipitation map of the Alps (1:925,000), and 27 small maps showing the location of all the stations, the distribution of different types of rainfall, the maximums, the minimums, etc.

The greatest value of the work lies in the compiling of the material, in the careful examination and interpretation of the data, the preparing of the great number of graphs, diagrams, and maps; also, its style which is easily readable and lacking the general long sentences of the German scientific writings.—*Sigismond R. Dietrich, Clark University.*

[5] Verteilung und jährlicher Gang der Niederschläge in den Alpen. K. Knoch und E. Reichel. Veroffentlichungen des Preusschen Meteorologischen Instituts, M. 375, abhandlungen, Bd. IX, No. 6, Berlin, 1930. Price, 13 R. M., 84 pp., maps, tables.

BIBLIOGRAPHY

By C. FITZHUGH TALMAN, in charge of Library

RECENT ADDITIONS

The following have been selected from among the titles of books recently received as representing those most likely to be useful to Weather Bureau officials in their meteorological work and studies:

Bosch, [J.] & Bosch, [A.]
Meteorologische Instrumente. Freiburg i. B. [1930.] unp. illus. 23 cm. [Katalog Nr. 25.]

Curry, J. C.
Climate and migrations. Washington. 1930. p. 423–435. figs. 24½ cm. (Smith. report, 1929.)

Gorton, A. F.
Forecasting seasonal precipitation in California. Its relation to electric power production. p. 996–1001. figs. 30½ cm. (Journ. Amer. inst. elec. engin., v. 49, Dec. 1930.)

Haeuser, J.
Ein Wolkenbruch von aussergewöhnlicher Stärke über München und Umgebung am 25. Juli 1929. München. n. d. unp. figs. 30 cm. (Wasserkraft und Wasserwirtschaft. Heft 18, 1930.)

Hanna, H. C.
Effect of volcanic dust on earth temperatures. 4 p. illus. 28 cm. (Volcano letter. Hawaiian volcano observ., National Park, Hawaii. no. 307. Nov. 13, 1930.)

Harrington, F. M., & Morgan, George W.
Dry-land shelter-belt tests at the northern Montana branch station. Bozeman. n. d. 16 p. illus. 22½ cm. (Univ. Montana. Agr. exp. sta. Bull. no. 235. Oct. 1930.)

Hettner, A.
Die Klimate der Erde. Leipzig. 1930. 115 p. figs. 22 cm. (Geogr. Schriften, Heft 5.)

Holdefleiss, Paul.
Agrarmeteorologie; die Abhängigkeiten der Ernteerträge von Wetter und Klima. Berlin. 1930. vii, 107 p. diagrs. 24 cm.

Jensen, I. J., & Harrington, F. M.
Dry-land shelter-belt tests at the Judith Basin branch station. Bozeman. n. d. 27 p. illus. 22 cm. (Univ. Montana Agr. exp. sta. Bull. no. 233. Oct., 1930.)

Johnson, James Halvor, *comp.*
Concerning the aurora borealis. [Berkeley, 1930.] 29 p. front. 23½ cm.

Kerner-Marilaun, Fritz.
Paläoklimatologie. Berlin. 1930. viii, 512 p. figs. 25 cm.

Libia. Ministero delle colonie.
Atlante meteorologico della Libia. n. p. 1930. 35 p. illus. plates. 25 cm.

Perlewitz, Paul.
Wetter und Mensch. Leipzig. 1929. 279 p. illus. plates. 19½ cm.

Pernice, Erich.
Der Spreewald als Gewitterherd. Ein Beitrag zur Erklärung der Vorgänge in Gewitterherdgebieten. Greifswald. 1930. 71 p. figs. 23 cm. (Inaug.-Dissert, Friedrich-Wilhelms-Univ. zu Berlin.)

Ridgley, Douglas C., & Koeppe, Clarence E.
College workbook in weather and climate. Bloomington. c1930. 128 p. figs. 26 cm.

Rochaix, [A.]
Atmosphère et climats ... 2ème éd. de Atmosphère et climats par J. Courmont et Ch. Lesieur. Paris. 1929. xx, 136 p. figs. 24½ cm. (Traité d'hygiène. 1.)

Vogel, Hans.
Die Atmosphärische Zirkulation über Australien. München. 1929. p. 179–237. plates. 24 cm. (Mitt. d. Geogr. Ges. München. Bd. 22, 2. Heft. Dez. 1929.)

SOLAR OBSERVATIONS

SOLAR AND SKY RADIATION MEASUREMENTS DURING DECEMBER, 1930

By HERBERT H. KIMBALL

For reference to description of instruments and exposures, and an account of the method of obtaining and reducing the measurements, the reader is referred to this volume of the REVIEW, page 26.

Table 1 shows that solar radiation intensities averaged above the normal intensity for December at Washington, D. C., and Lincoln, Nebr., and slightly below normal at Madison, Wis.

Table 2 shows an excess in the total solar radiation received on a horizontal surface directly from the sun and diffusely from the sky at Washington, New York, and Fresno, and a deficiency at Madison, Lincoln, Chicago, and La Jolla.

For the year, as shown in the last line of Table 2, there have been unimportant percentage departures in the total radiation received, except at Washington, where there was an excess of 6.9 per cent, and at La Jolla, where there was a deficiency of 1.5 per cent, as compared with the annual average at the respective stations.

Skylight polarization measurements were obtained at Washington on 3 days, and give a mean percentage of 58, with a maximum of 62 on the 16th. At Madison, measurements were obtained on the 9th only, and gives a percentage of 72. Snow covered the ground throughout the month at this station except from the 5th to the 12th. At both stations the measurements obtained are close to average values for December at the respective stations.

TABLE 1.—*Solar radiation intensities during December, 1930*

[Gram-calories per minute per square centimeter of normal surface]

Washington, D. C.

Date	Sun's zenith distance: 8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass: A. M.					P. M.				Local mean solar time
	e.	5.0	4.0	3.0	2.0	[1] 1.0	2.0	3.0	4.0	5.0	e.
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
Dec. 2	1.19	.....	0.84	1.08	1.28	.....	.....	1.06	0.89	0.80	1.02
Dec. 3	2.16	0.90	0.95	1.10	1.29	.....	1.29	1.10	0.96	0.84	1.88
Dec. 16	1.07	0.99	1.16	1.25	1.37	.....	1.37	1.23	1.06	0.93	2.49
Dec. 18	2.87	.....	.....	.....	1.26	.....	.....	.....	.....	.....	1.52
Dec. 21	3.15	.....	.....	.....	1.32	.....	.....	.....	.....	.....	4.17
Dec. 23	2.74	.....	.....	.....	0.91	.....	.....	.....	.....	.....	2.74
Means	.....	(0.94)	0.98	1.14	1.24	.....	(1.33)	1.13	0.97	0.86	.....
Departures	.....	+0.15	+0.08	+0.09	+0.01	.....	+0.01	+0.10	+0.06	+0.06	.....

Madison, Wis.

Dec. 1	1.02	1.06	1.20	1.29	.....	.....	.....	.....	.....	.....	0.51
Dec. 8	3.30	.....	.....	.....	.....	.....	.....	0.98	.....	.....	3.99
Dec. 9	3.99	0.93	1.05	1.18	.....	.....	.....	1.22	.....	.....	4.37
Dec. 15	1.52	0.89	1.16	1.30	.....	.....	.....	.....	.....	.....	1.68
Dec. 16	1.32	0.93	1.12	1.30	.....	.....	.....	.....	.....	.....	2.06
Dec. 17	1.37	0.72	0.85	1.01	.....	.....	.....	.....	.....	.....	1.96
Dec. 23	1.78	.....	.....	1.30	.....	.....	.....	.....	.....	.....	1.68
Dec. 30	1.19	.....	1.14	1.21	.....	.....	.....	.....	.....	.....	1.12
Dec. 31	3.45	.....	.....	.....	.....	.....	.....	1.27	.....	.....	1.45
Means	.....	0.91	1.09	1.23	.....	.....	.....	1.16	.....	.....	.....
Departures	.....	−0.05	−0.01	+0.02	.....	.....	.....	−0.08	.....	.....	.....

[1] Extrapolated.

TABLE 1.—*Solar radiation intensities during December, 1930*—Con.

Lincoln, Nebr.

Date	Sun's zenith distance: 8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass: A. M.					P. M.				Local mean solar time
	e.	5.0	4.0	3.0	2.0	[1] 1.0	2.0	3.0	4.0	5.0	e.
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
Dec. 8	3.15	0.71	0.91	1.09	.....	.....	.....	1.21	0.96	0.89	4.57
Dec. 10	4.17	.....	.....	.....	.....	.....	.....	1.27	1.09	1.02	4.57
Dec. 11	3.15	0.98	1.07	1.22	.....	.....	.....	.....	.....	.....	3.45
Dec. 19	2.62	.....	1.12	1.35	.....	.....	.....	.....	.....	.....	3.00
Dec. 23	2.49	.....	1.05	1.22	.....	.....	.....	.....	.....	.....	3.63
Dec. 28	2.26	.....	.....	1.24	.....	.....	.....	1.12	.....	.....	3.00
Dec. 29	2.87	.....	1.13	.....	.....	.....	.....	.....	.....	.....	3.00
Dec. 30	1.78	.....	1.05	1.20	.....	.....	.....	1.24	.....	.....	2.49
Dec. 31	2.87	.....	1.22	1.34	.....	.....	.....	1.35	1.18	1.05	2.87
Means	.....	(0.84)	1.08	1.24	.....	.....	.....	1.24	1.08	0.99	.....
Departures	.....	−0.11	−0.02	+0.03	.....	.....	.....	+0.08	+0.01	+0.03	.....

TABLE 2.—*Total solar radiation (direct+diffuse) received on a horizontal surface*

GRAM-CALORIES PER SQUARE CENTIMETER

Week beginning—	Average daily totals: Washington	Madison	Lincoln	Chicago	New York	Pittsburgh	Gainesville	Fresno	La Jolla	Miami
1930	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Dec. 3	141	87	129	36	79	80	210	214	234	280
Dec. 10	159	101	138	53	105	54	213	214	262	289
Dec. 17	154	116	169	51	106	38	92	231	271	198
Dec. 24 [1]	147	111	184	67	89	74	190	200	233	224
	Departures from weekly normals									
Dec. 3	−6	−34	−40	−34	−10	.....	.....	+25	−39	.....
Dec. 10	+20	−11	−19	−16	+16	.....	.....	+35	−15	.....
Dec. 17	+12	−7	−3	−25	+12	.....	.....	+58	−3	.....
Dec. 24	+5	−16	+3	−15	−9	.....	.....	+38	−17	.....
Accumulated departure at end of year	+8,405	+1,314	−808	+34	+1,230	.....	.....	−1,006	−1,947	.....
Percentage departures for the year	+6.9	+1.1	−0.6	±0.0	+1.3	.....	.....	−0.6	−1.5	.....

[1] 8-day means.

POSITIONS AND AREAS OF SUN SPOTS

[Communicated by Capt. J. F. Hellweg, Superintendent United States Naval Observatory. Data furnished by Naval Observatory, in cooperation with Harvard, Yerkes, Perkins, and Mount Wilson Observatories. The differences of longitude are measured from central meridian, positive west. The north latitudes are plus. Areas are corrected for foreshortening and are expressed in millionths of sun's visible hemisphere. The total area, including spots and groups, is given for each day in the last column]

Date	Eastern standard civil time	Heliographic: Diff. long.	Longitude	Latitude	Area: Spot	Group	Total area for each day
1930	*h m*	°	°	°			
Dec. 1 (Naval Observatory)	12 23	−5.0	37.8	+8.0	46	.....	.....
		+17.0	59.8	+8.5	.....	15	.....
		+37.5	80.3	+14.5	.....	170	.....
		+63.5	106.3	−9.0	.....	309	540
Dec. 2 (Naval Observatory)	12 32	+8.0	37.5	+9.0	.....	77	.....
		+56.0	85.5	+14.0	.....	93	.....
		+77.0	106.5	−9.0	.....	309	479

POSITIONS AND AREAS OF SUN SPOTS—Continued

Date	Eastern standard civil time	Heliographic Diff. long.	Heliographic Longitude	Heliographic Latitude	Area Spot	Area Group	Total area for each day
1930	h m	°	°	°			
Dec. 3 (Naval Observatory)	11 45	+20.5	37.3	+9.0	.....	93	.....
		+71.0	87.8	+14.0	.....	93	186
Dec. 4 (Naval Observatory)	10 47	+33.5	37.6	+8.5	.....	93	.....
		+75.5	79.6	+16.5	.....	46	139
Dec. 5 (Mount Wilson)	12 50	+49.0	38.9	+9.0	.....	32	32
Dec. 6 (Mount Wilson)	13 40	+60.0	36.2	+10.0	9	.....	9
Dec. 7 (Mount Wilson)	12 30	+80.0	43.6	+9.0	16	.....	16
Dec. 8 (Naval Observatory)	10 46	.....	.....	.....	.....	.....	(*)
Dec. 9 (Naval Observatory)	13 33	−74.0	222.7	+5.0	.....	170	170
Dec. 10 (Perkins Observatory)	11 37	−64.5	220.2	+5.0	.....	186	186
Dec. 11 (Mount Wilson)	14 0	−55.0	215.2	+3.0	.....	11	.....
		−48.0	222.2	+11.0	.....	5	.....
		−48.0	222.2	+5.0	83	.....	.....
		−37.0	233.2	+17.0	.....	9	108
Dec. 12 (Naval Observatory)	11 5	−37.0	221.6	+6.5	.....	93	.....
		−36.0	222.6	+10.5	15	.....	.....
		+26.0	284.6	+11.5	9	.....	117
Dec. 13 (Naval Observatory)	11 40	−22.5	222.6	+6.0	.....	123	123
Dec. 14 (Mount Wilson)	14 10	−16.0	214.5	+6.0	14	.....	.....
		−5.0	225.5	+6.0	.....	80	.....
		+10.0	240.5	−12.0	.....	90	184
Dec. 15 (Naval Observatory)	11 44	+7.0	225.7	+6.5	19	.....	.....
		+21.5	240.2	−12.0	.....	77	96
Dec. 16 (Naval Observatory)	11 57	+32.0	237.4	−11.0	31	.....	.....
		+38.5	243.9	−14.0	.....	62	93
Dec. 17 (Yerkes Observatory)	12 43	−75.0	116.8	−7.1	260	.....	.....
		−67.8	124.0	−8.6	266	.....	526
Dec. 18 (Naval Observatory)	11 10	−69.5	110.0	−10.0	62	.....	.....
		−55.0	124.5	−11.5	.....	31	.....
		+48.0	227.5	+12.0	31	.....	.....
		+60.0	239.5	−12.0	.....	31	.....
		+67.5	247.0	−13.0	.....	31	186
Dec. 19 (Mount Wilson)	14 45	−82.0	82.4	+17.0	19	.....	.....
		−55.0	109.4	−9.0	162	.....	.....
		−49.0	115.4	+10.0	.....	30	.....
		−41.0	123.4	−11.0	.....	11	.....
		−26.0	138.4	−8.0	.....	4	.....
		+61.0	225.4	+11.0	.....	166	.....
		+80.0	244.4	−15.0	.....	30	422
Dec. 20 (Naval Observatory)	13 54	−40.0	111.6	−9.0	123	.....	.....
		−33.0	118.6	+10.0	31	.....	154
Dec. 21 (Naval Observatory)	11 10	−29.0	110.9	−9.5	.....	108	.....
		−21.0	118.9	+9.0	15	.....	123
Dec. 22 (Naval Observatory)	11 49	−39.5	86.9	+12.0	31	.....	.....
		−12.0	114.4	−9.5	.....	108	.....
		−9.5	116.9	+9.8	31	.....	170
Dec. 23 (Naval Observatory)	11 28	−1.5	111.9	−9.5	.....	108	.....
		+30.0	143.4	+2.0	.....	62	170
Dec. 24 (Naval Observatory)	11 9	−16.5	83.9	+15.0	31	.....	.....
		−11.5	88.9	+13.0	.....	62	.....
		+12.5	112.9	−8.5	.....	77	170
Dec. 25 (Naval Observatory)	11 5	+2.5	89.8	+13.0	.....	62	.....
		+6.5	93.8	+16.0	45	.....	.....
		+26.0	113.3	−8.5	.....	31	138

* No spots.

POSITIONS AND AREAS OF SUN SPOTS—Continued

Date	Eastern standard civil time	Heliographic Diff. long.	Heliographic Longitude	Heliographic Latitude	Area Spot	Area Group	Total area for each day
1930	h m	°	°	°			
Dec. 26 (Mount Wilson)	14 15	−52.0	20.4	+10.0	.....	6	.....
		−33.0	39.4	+9.0	.....	6	.....
		+5.0	77.4	+19.0	.....	4	.....
		+17.0	89.4	+14.0	.....	115	.....
		+39.0	111.4	+7.0	5	.....	.....
		+39.0	111.4	−9.0	.....	4	140
Dec. 27 (Naval Observatory)	12 46	−32.0	28.0	+11.5	.....	108	108
Dec. 28 (Mount Wilson)	13 0	+45.0	91.7	+13.0	72	.....	72
Dec. 29 (Naval Observatory)	12 33	+68.5	102.3	+17.0	46	.....	46
Dec. 30 (Naval Observatory)	10 45	+70.0	91.6	+17.0	.....	62	62
Dec. 31 (Naval Observatory)	11 17	.....	.....	.....	.....	.....	(*)
Mean daily area for December	.....	.....	.....	.....	.....	.....	160

* No spots.

PROVISIONAL SUN-SPOT RELATIVE NUMBERS FOR DECEMBER, 1930[1]

[Data furnished through the courtesy of Prof. W. Brunner, University of Zurich, Switzerland]

December, 1930	Relative numbers	December 1930	Relative numbers	December, 1930	Relative numbers
1	a 47	11	21	21	c 35
2	36	12	.....	22	28
3	35	13	15	23	a 31
4	21	14	22	24	45
5	8	15	a 22	25	a 52
6	8	16	20	26	53
7	7	17	d 30	27	41
8	c	18	d 52	28	26
9	E 8	19	Wcc 50	29	9
10	19	20	42	30	15
				31	14

Mean: 28 days=28.0.

[1] Dependent alone on observations at Zurich and its station at Arosa.

a=Passage of an average-sized group through the central meridian.
b=Passage of a large group through the central meridian.
c=New formation of a large or average-sized center of activity: E, on the eastern part of the sun's disk; W, on the western part; M, in the central zone.
d=Entrance of large or average-sized center of activity on the east limb.

AEROLOGICAL OBSERVATIONS

By L. T. SAMUELS

Free-air temperatures during December were below normal at all stations except from the surface to 2,000 meters at Ellendale. (See Table 1.) The largest departures occurred at Due West and Groesbeck.

The free-air relative humidities were mostly above normal with the largest departures occurring in the higher levels at Ellendale.

Free-air vapor pressures, in agreement with the temperatures, were below normal at all stations except Ellendale, with the largest departures occurring at Due West and Groesbeck.

It is interesting to note that notwithstanding the supernormal relative humidities and vapor pressures at Ellendale, the total precipitation for the month was the lowest of record (14 years), being only 0.07 inch. However, the month had 15 cloudy and 10 partly cloudy and 6 clear days.

Free-air resultant winds for the month at the 1,000-meter level contained a pronounced westerly component at all stations east of the Rockies and north of latitude 30°. The resultant velocities ranged from 4 meters per second in the southern section to 8 meters per second in the north. Along the Pacific coast and northern Rocky Mountain region the resultant winds were variable and the velocities mostly light.

At 3,000 meters a westerly component prevailed at all stations, including Key West, with the highest resultant velocities in the north-central portion of the country.

The monthly resultants for a representative group of stations are shown in Table 3.

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during December, 1930*

TEMPERATURE (° C.)

Altitude (*Meters*) m. s. l.	Broken Arrow, Okla. (233 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Groesbeck, Tex. (141 meters)		Royal Center, Ind. (225 meters)	
	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal
Surface	2.6	−1.6	2.5	−4.5	−5.6	+3.9	6.5	−2.6	−2.2	−0.5
500	2.9	−0.8	2.7	−4.1	−5.6	+3.8	6.1	−2.4	−3.1	0
1,000	1.8	−1.4	2.6	−3.6	−4.4	+2.6	4.3	−4.1	−3.8	−0.1
1,500	0.4	−2.4	1.8	−3.1	−5.2	+1.3	3.0	−4.5	−4.4	−0.5
2,000	−1.2	−2.7	0.0	−3.3	−7.4	+0.2	1.7	−4.3	−5.7	−0.6
2,500	−3.6	−3.1	−2.1	−3.4	−9.8	−0.2	−0.1	−4.1	−7.3	−0.4
3,000	−5.7	−2.9	−4.3	−3.4	−12.4	−0.3	−1.7	−3.4	−9.6	−0.5
4,000	−10.9	−2.8	−10.2	−4.2	−19.3	−1.7			−17.4	−2.6

RELATIVE HUMIDITY (%)

Surface	79	+9	78	+4	82	+1	77	+3	82	+2
500	66	+2	71	+5	81	+2	65	−2	77	0
1,000	57	+4	65	+5	71	+6	59	+2	71	+5
1,500	53	+10	58	+2	67	+9	48	−1	58	+2
2,000	51	+13	57	+5	69	+14	41	−1	52	0
2,500	48	+12	55	+7	69	+14	40	+1	49	−2
3,000	44	+8	51	+7	67	+13	41	+5	43	−8
4,000	38	+4	53	+10	73	+20			52	0

VAPOR PRESSURE (*mb.*)

Surface	5.94	−0.33	5.87	−2.17	3.30	+0.62	7.70	−1.73	4.44	−0.19
500	5.08	−0.49	5.45	−1.80	3.27	+0.63	6.35	−1.97	3.81	−0.24
1,000	4.00	−0.48	4.91	−1.38	3.04	+0.63	5.02	−1.75	3.18	−0.15
1,500	3.27	−0.32	4.01	−1.26	2.66	+0.47	3.66	−1.60	2.56	−0.18
2,000	2.75	−0.16	3.50	−0.76	2.27	+0.40	2.89	−1.07	2.05	−0.24
2,500	2.19	−0.19	2.92	−0.47	1.85	+0.27	2.57	−0.59	1.77	−1.19
3,000	1.82	−0.19	2.60	−0.13	1.49	+0.23	2.47	−0.07	1.39	−0.31
4,000	1.39	−0.06	2.43	+0.45	0.85	+0.07			1.09	−0.10

TABLE 2.—*Free-air data obtained at naval air stations during December, 1930*

Altitude (*meters*) m. s. l.	Temperature (°C.)				Relative humidity (%)			
	Hampton Roads, Va.	Pensacola, Fla.	San Diego, Calif.	Washington, D. C.	Hampton Roads, Va.	Pensacola, Fla.	San Diego, Calif.	Washington, D. C.
Surface	2.3	8.3	15.1	−1.3	70	84	49	74
500	1.0	7.9	14.0	−1.7	61	77	47	70
1,000	−0.6	7.1	13.0	−2.4	56	70	37	64
2,000	−2.6	5.7	9.0	−4.3	37	53	22	54
3,000	−7.6	2.1	3.5	−7.4	41	47	14	46
4,000				−11.6				53

TABLE 3.—*Free-air resultant winds (meters per second) based on pilot balloon observations made near 7 a. m. (E. S. T.) during December, 1930*

Altitude (meters) m.s.l.	Broken Arrow, Okla. (233 meters)		Brownsville, Tex. (12 meters)		Burlington, Vt. (132 meters)		Cheyenne, Wyo. (1,873 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Groesbeck, Tex. (139 meters)		Havre, Mont. (762 meters)		Jacksonville, Fla. (14 meters)		Key West, Fla. (11 meters)		Los Angeles, Calif. (127 meters)		Medford, Oreg. (410 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°		°		°		°		°		°		°	
Surface	N 72 W	1.0	N 27 W	1.4	S 2 E	2.2	N 69 W	4.9	N 13 E	1.2	N 70 W	3.3	N 29 W	1.5	S 62 W	3.5	N 37 W	1.8	N 35 E	3.7	N 2 W	1.7	S 4 W	0.2
500	N 53 W	2.9	N 42 E	3.0	S 37 W	5.1			N 6 W	2.8	N 72 W	4.3	N 26 W	2.8			N 17 W	3.9	N 85 E	5.3	N 81 E	1.6	N 45 E	0.4
1,000	N 54 W	6.4	N 43 E	1.1	S 76 W	6.6			N 47 W	3.0	N 43 W	8.8	N 28 W	3.4	S 76 W	7.2	N 68 W	4.9	S 81 E	4.7	S 84 E	0.7	S 40 E	3.0
1,500	N 52 W	7.8	S 79 W	1.8	S 86 W	7.9			N 66 W	5.7	N 60 W	8.8	N 49 W	2.5	N 73 W	10.1	N 73 W	8.3	S 19 E	4.2	N 61 E	0.1	S 20 W	3.2
2,000	N 64 W	9.3	S 74 W	3.6	S 76 W	8.0	N 66 W	7.8	N 74 W	8.6	N 53 W	10.6	N 60 W	3.8	N 69 W	10.0	N 71 W	9.2	S 1 W	4.6	N 3 E	0.7	S 42 W	4.7
2,500	N 58 W	11.0	S 68 W	5.4	S 82 W	8.4	N 52 W	11.1	N 73 W	9.7	N 45 W	11.5	N 70 W	6.3	N 65 W	9.0	N 67 W	8.6	S 35 W	5.3	N 2 E	1.4	S 46 W	7.4
3,000	N 80 W	11.3	N 84 W	7.2	S 84 W	9.4	N 42 W	9.8	N 78 W	9.5	N 55 W	10.0	N 77 W	9.0	N 64 W	9.7	N 72 W	12.7	S 50 W	5.0	N 13 E	1.8	S 54 W	7.4
4,000			S 70 W	11.8			N 42 W	8.6	N 76 W	10.5													S 68 W	6.3
5,000							N 74 W	5.5																

Altitude (meters) m.s.l.	Memphis, Tenn. (145 meters)		Modena, Utah (1,665) meters)		New Orleans, La. (25 meters)		Omaha, Nebr. (299 meters)		Phoenix, Ariz. (356 meters)		Royal Center, Ind. (225 meters)		Salt Lake City, Utah (1,294 meters)		San Francisco, Calif. (8 meters)		Sault Ste. Marie, Mich. (198 meters)		Seattle, Wash. (14 meters)		Sheridan, Wyo. (1,153) meters)		Washington, D. C. (10 meters)	
	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
	°		°		°		°		°		°		°		°		°		°		°		°	
Surface	N 58 W	0.4	N 86 W	1.2	N 32 E	1.4	N 34 W	1.7	S 89 E	3.3	S 63 W	1.3	S 45 E	1.1	N 70 E	0.6	N 43 W	0.6	S 29 E	1.4	N 57 W	0.8	N 51 W	1.7
500	N 43 W	2.0			N 31 E	3.0	N 45 W	3.8		E 3.8	S 72 W	4.4			N 44 E	2.8	N 79 W	2.7	S 5 E	4.7			N 65 W	4.9
1,000	N 65 W	6.3			N 25 W	1.6	N 46 W	6.7	N 75 E	4.0	N 87 W	6.6			N 19 E	2.8	N 70 W	4.9	S 11 W	5.7			N 59 W	7.4
1,500	N 71 W	7.3			N 53 W	3.7	N 57 W	11.2	N 86 E	2.4	S 85 W	7.5	N 63 E	0.2	N 29 W	2.3	N 69 W	6.7	S 26 W	5.7	N 56 W	5.3	N 62 W	6.4
2,000	N 64 W	8.2	N 39 E	2.3	N 53 W	6.6	N 62 W	13.4	N 51 E	1.5	S 83 W	8.8	N 87 W	0.7	N 49 W	1.2	N 66 W	7.1	S 32 W	7.3	N 49 W	8.6	N 83 W	8.4
2,500	N 60 W	7.4	N 7 E	2.1	N 67 W	8.8	N 57 W	14.6	N 8 W	2.8	N 83 W	7.8	N 54 W	1.7	S 66 W	1.8	N 59 W	7.3	S 31 W	7.3	N 51 W	10.0	S 89 W	10.4
3,000	N 79 W	5.6	N 12 W	3.9	N 73 W	8.2	N 45 W	11.6	N 17 W	3.9	N 58 W	7.1	N 39 W	2.6	S 45 W	1.8	N 37 W	7.8	S 48 W	9.5	N 55 W	9.7		
4,000			N 31 W	5.9					N 36 W	6.0			N 88 W	2.4							N 49 W	10.4		
5,000			N 54 W	6.5					N 48 W	2.5											N 49 W	5.2		

TABLE 4.—*Observations by means of kites, captive and limited height sounding balloons during December, 1930*

	Broken Arrow, Okla.	Due West, S. C.	Ellendale, N. Dak.	Groesbeck, Tex.	Royal Center, Ind.
Mean altitudes, (meters) m. s. l., reached during month	2,839	2,193	2,649	2,184	2,687
Maximum altitude (meters), m. s. l., reached	4,212	4,588	4,794	3,397	4,588
Number of flights made	30	32	32	23	29
Number of days on which flights were made	29	31	29	23	28

In addition to the above there were approximately 176 pilot balloon observations made daily at 60 Weather Bureau stations in the United States.

AEROLOGICAL OBSERVATIONS FOR THE YEAR 1930

By L. T. SAMUELS

Free-air temperatures during 1930 were slightly above normal in the northern part of the country and slightly below in the southern part. (Table 1.) There was a tendency for the negative departures to increase in magnitude with elevation.

Free-air relative humidity departures were mostly negative and of small magnitude. Negative relative humidity departures occurred with negative temperature departures at most stations and levels and this appears significant in connection with the general drought which prevailed.

Vapor pressure departures were negative except at Ellendale and in the upper levels at Broken Arrow, Due West, and Royal Center. The largest negative departures occurred at Groesbeck.

From Table 2 it is found that the total number of flights (kites, captive, and limited-height sounding balloons) made during the year at the five stations was 1,749. This is an average of 350 flights per station. The average altitude reached was 2,743 meters above sea level. The highest elevation (8,384 meters) reached during the year was that of a limited-height sounding balloon at Ellendale on September 29, 1930. In addition there were 40 sounding balloon observations made at 10 Weather Bureau stations during January and 36 at Royal Center during September, the latter being the international month.

TABLE 1. *Free-air temperatures, relative humidities, and vapor pressures during year 1930*

TEMPERATURE (°C.)

Altitude meters m. s. l.	Broken Arrow, Okla. (233 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Groesbeck, Tex. (141 meters)		Royal Center, Ind. (225 meters)	
	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal
Surface	14.3	−1.2	15.2	−1.3	6.1	+0.5	16.2	−1.9	10.7	−0.3
500	14.0	−0.1	14.1	−0.6	5.9	+0.4	15.4	−0.9	9.3	+0.3
1,000	12.6	+0.3	12.0	−0.4	5.0	+0.4	14.1	−0.6	7.1	+0.3
1,500	10.6	+0.1	9.5	−0.5	3.5	+0.3	12.2	−0.8	4.7	−0.1
2,000	8.2	−0.1	6.8	−0.8	1.4	+0.4	10.0	−0.9	2.6	−0.1
2,500	5.5	−0.2	4.2	−0.9	−1.2	+0.4	7.4	−1.1	0.2	−0.2
3,000	2.6	−0.3	1.6	−0.9	−3.9	+0.5	4.8	−1.1	−2.3	−0.2
4,000	−3.8	−1.0	−3.8	−0.8	−9.9	+0.1	−0.8	−1.2	−8.2	−0.9
5,000	−9.6	−1.2	−9.4	−0.8	−15.9	−0.2			−14.0	−0.7

RELATIVE HUMIDITY (%)

Surface	69	+1	69	+1	70	−2	78	+4	70	0
500	63	−2	64	−2	70	−1	70	−1	67	−2
1,000	57	−4	61	−3	64	0	59	−4	64	−2
1,500	53	−4	59	−3	59	0	52	−3	60	−2
2,000	50	−3	57	−2	56	−1	48	−1	56	−2
2,500	48	−2	55	−1	56	0	45	0	53	−1
3,000	47	−2	53	0	55	0	43	+1	51	−1
4,000	48	+2	53	+3	55	+2	32	−7	47	−1
5,000	40	−3	56	+10	51	+1			42	−5

VAPOR PRESSURE (*mb.*)

Surface	12.93	−0.83	13.58	−0.42	8.03	−0.04	16.21	−0.57	10.50	−0.28
500	11.70	−0.46	11.85	−0.52	7.90	+0.04	13.79	−0.88	9.20	−0.16
1,000	9.64	−0.33	9.71	−0.70	6.56	+0.18	10.26	−1.34	7.61	−0.14
1,500	7.84	−0.21	7.90	−0.71	5.42	+0.15	7.94	−1.04	6.20	−0.07
2,000	6.21	−0.13	6.33	−0.55	4.39	+0.08	6.23	−0.70	4.82	−0.20
2,500	4.88	−0.08	5.01	−0.42	3.56	+0.03	5.02	−0.46	3.74	−0.12
3,000	4.00	+0.07	4.04	−0.27	2.90	+0.06	4.24	−0.14	3.04	+0.01
4,000	2.81	+0.36	2.83	+0.02	1.75	−0.08	1.57	−1.31	1.91	+0.07
5,000	1.91	+0.38	2.65	+0.71	0.96	−0.22			1.05	−0.26

TABLE 2.—*Observations by means of kites, captive and limited height sounding balloons during 1930*

	Broken Arrow, Okla.	Due West, S. C.	Ellendale, N. Dak.	Groesbeck, Tex.	Royal Center, Ind.
Mean altitudes (meters), m. s. l., reached during month	2,793	2,644	3,004	2,327	2,940
Maximum altitude (meters), m. s. l., reached and date	6,397	5,789	[1] 8,384	4,485	[2] 8,201
Number or flights made	354	359	387	302	347
Number of days on which flights were made	355	337	348	278	334

[1] Limited height sounding balloon observation.
[2] Captive balloon observation (breakaway).

In addition to the above there were approximately 150 pilot balloon observations made daily at nearly 60 weather bureau stations in the United States.

WEATHER IN THE UNITED STATES

THE WEATHER ELEMENTS

By M. C. BENNETT

GENERAL SUMMARY

December was mostly mild east of the Rocky Mountains and generally dry. In the west Gulf section and the Southeastern States, as far north as the Potomac and Ohio Rivers, the temperature for the month was below normal, with freezing temperatures extending into Florida, while in the central and northern regions, from the Mississippi Valley to the Rocky Mountains, abnormally high temperatures for the season prevailed; but in the Great Basin it was unusually cold. However, in the far Southwest and Pacific coast districts, near normal temperatures were the rule.

Generous amounts of precipitation were received in many places in the South Atlantic States and in eastern West Virginia, but many of the Atlantic coast districts had less than normal. From the Ohio and Missouri Valleys northward, the totals were small, with large areas receiving less than one-fourth of the normal, while in much of Texas and Oklahoma more than the normal was received. But from the Rocky Mountains westward the month was generally dry, with considerable areas in the southern portion of the Plateau and Pacific regions receiving no appreciable precipitation.

TEMPERATURE

While a cold snap swept quickly over the north-central and northeastern areas as the month started, yet the first half of December averaged warmer than normal over nearly the whole country, except that portions of the Atlantic States and the lower Lake region averaged slightly colder than normal, while decidedly cold weather persisted in the northern and central Plateau areas.

From the middle of the month onward warm weather persisted in the north-central portion from Wisconsin and northern Illinois to central Montana and northeastern Wyoming, and this period was slightly warmer than normal in New England and much of New York, Washington, and California. The greater part of the country, however, was cooler than normal during most of this half-month. The southeastern portion and the Plateau region showed fairly large negative departures, low temperatures prevailing in the former from the 17th to the 24th, while

southern Idaho and districts adjacent were remarkably cold throughout the final decade.

The month averaged warmer than normal in practically all northern districts, and throughout most of the Missouri Valley and the Plains. The Dakotas averaged about 7° warmer than normal; while the South Atlantic and Gulf districts averaged 3° to 5° colder, and most of Idaho and Utah from 7° to 10° or more colder. At Salt Lake City, Utah, the month was the coldest December in a record of 57 years, and some stations on the east Gulf coast had about the coldest December of record.

In departure of mean temperature, November and December of 1930 were surprisingly alike. The most notable differences were in the Dakotas and the eastern portions of the States next westward, where November had been only slightly warmer than normal, but the following month brought a marked excess of temperature, and from Mississippi northeastward over the Ohio Valley to western New York, where November had been warmer than normal, but December was colder.

The highest temperatures occurred usually between the the 8th and 11th, save in some Atlantic States on the 1st. The lowest temperatures showed less uniformity in time of occurrence, but were reached mainly between the 15th and 27th. As a rule, the temperature extremes were not noteworthy, but in Nebraska this was the first December in a record of 55 years when not one station recorded a temperature of zero or below.

PRECIPITATION

In eastern and south-central districts the precipitation came largely during the first and last weeks, save that parts of the South Atlantic States had considerable rain or snow about the 17th. The second week was the time of greatest precipitation in the far Northwest.

December, for the country as a whole, was a month of scanty precipitation, especially from California eastward and northeastward to the middle and northern portions of the Rocky Mountain and Plains regions, and to a considerable extent still farther eastward in the upper Mississippi Valley, the upper Lake region, and the States just north of the Ohio River. In the Pacific Northwest there was mainly less than half of the normal precipitation. Oklahoma, with most of western and north-central Texas, had more than normal rainfall, owing chiefly to the rains of the first week. However, the Gulf States, the Appalachian region, and the Northeast usually had about two-thirds to four-fifths of the normal amounts, but much of the South Atlantic region had more than normal, especially central Florida and the eastern parts of the Carolinas.

SNOWFALL

The snowfall of December was less than normal in nearly all districts west of the Appalachian Mountains, and was particularly scanty from California northeastward to southern Minnesota and central and northern Wisconsin. Northern and western Oklahoma and many adjacent districts had about as much snow as normal, likewise part of eastern Iowa; also from the western end of Lake Superior to north-central North Dakota the amounts were seasonable.

From central Pennsylvania southward practically all the Appalachian region had considerable snowfall, some portions having decidedly large amounts compared with what December usually brings. Nearly all of Tennessee had moderate snowfall, and north-central North Carolina and southern Virginia comparatively large amounts. New York and Vermont had mainly somewhat less snow than normal, but interior New England elsewhere more than normal.

SUNSHINE AND RELATIVE HUMIDITY

Much cloudy weather prevailed throughout the East and as far westward as the Mississippi Valley, in the west Gulf States, and the northern portion of the Pacific and Plateau regions, while in the south Pacific region much sunshiny weather prevailed. Elsewhere, about the normal amount of sunshine for December was received. The relative humidity was generally near or slightly above the normal over much of the country east of the Rocky Mountains, notwithstanding the fact that there was a general deficiency of precipitation in most sections. However, from the Rocky Mountains westward, except in the Great Basin, it was generally below the average for the month.

SEVERE LOCAL STORMS, DECEMBER, 1930

[The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A more complete statement will appear in the Annual Report of the Chief of Bureau]

Place	Date	Time	Width of path, yards	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Port Huron, Mich.	15					Heavy snow	Traffic of all kinds delayed	Official, U. S. Weather Bureau.
Goldsboro, N. C., and vicinity.	17					Snow and sleet	Some damage, character not reported	Do.
Wichita, Kans.	17					Glaze	Number of serious auto accidents	Do.
Nantucket, Mass.	27	3:30 p. m.				Gale	High tide caused considerable damage to small boats and the water front.	Do.
Marquette, Mich.	29-31					Snow and wind	Outdoor activities hampered; auto and railway transportation tied up; wind very severe at times.	Do.

RIVERS AND FLOODS

By MONTROSE W. HAYES

Minor floods in Texas were mentioned in the article on "Rivers and Floods" in the October, 1930, REVIEW, but in the text no reference was made to a flood in the first half of October in the Colorado River of Texas. Belated reports indicate the Colorado flood was potentially the most serious in the State, but it passed off without causing any important damage. Bottom lands were flooded, but by taking timely heed of the warnings corn was hauled from the bottomlands, and cattle and hogs were driven to higher ground.

Floods occurred in November in some of the streams of Georgia, Alabama, western Florida, and eastern Louisiana. (See table of flood stages.) They caused no serious damage. The overflow of the Choctawhatchee appears to have been watched with absorbing interest and with gratification by the residents and interests along the stream, as this was the first test of the new Choctawhatchee flood warning system.

In December there were some local overflows in the Savannah River Basin and in eastern Louisiana and Texas, but they were of minor importance.

Table of flood stages in November and December, 1930

River and station	Flood stage	Above flood stages—dates		Crest	
		From—	To—	Stage	Date
ATLANTIC DRAINAGE	*Feet*			*Feet*	
Savannah: Ellenton, S. C.	13	Nov. 15	Nov. 23	17.2	Nov. 20, 21.
		Dec. 8	Dec. 12	16.5	Dec. 10.
Ogeechee: Meldrim, Ga.	6	Nov. 27	Dec. 14	7.6	Dec. 1, 2.
Ocmulgee: Abbeville, Ga.	11	Nov. 24	Nov. 25	11.3	Nov. 24, 25.
EAST GULF DRAINAGE					
Apalachicola: Blountstown, Fla.	20	Nov. 20	Nov. 23	20.9	Nov. 22.
Flint: Albany, Ga.	20	Nov. 21	Nov. 21	20.1	Nov. 21.
Chattahoochee:					
Columbus, Ga.	20	Nov. 17	Nov. 17	25.2	Nov. 17.
Alaga, Ala.	30	Nov. 18	Nov. 20	34.9	Nov. 19.
Choctawhatchee: Caryville, Fla.	12	Nov. 17	Nov. 24	13.2	Nov. 19, 20.
Black Warrior: Tuscaloosa, Ala.	46	..do.....	Nov. 18	49.5	Nov. 17.
West Pearl: Pearl River, La.	13	Nov. 20	Nov. 24	14.1	Nov. 22.
		Dec. 6	Dec. 14	14.6	Dec. 11.
MISSISSIPPI DRAINAGE					
Sulphur: Ringo Crossing, Tex.	20	Dec. 1	Dec. 1	20.5	Dec. 1.
		Dec. 5	Dec. 8	23.3	Dec. 6.
WEST GULF DRAINAGE					
Trinity:					
Dallas, Tex.	28	Dec. 1	Dec. 1	29.6	Dec. 1.
		Dec. 5	Dec. 9	33.6	Dec. 6.
Trinidad, Tex.	28	Dec. 9	Dec. 11	28.8	Dec. 10.
Liberty, Tex.	25	Dec. 8	..do.....	25.1	Dec. 9, 10.

WEATHER OF THE ATLANTIC AND PACIFIC OCEANS

NORTH ATLANTIC OCEAN

By F. A. YOUNG

December is normally one of the stormiest months of the year over the North Atlantic, and the conditions during the current month could not be called unusual over the greater part of the ocean, although up to time of writing, nearly 100 vessels have rendered storm reports. Along the American coast between the thirty-fifth and fortieth parallels, the number of days with gales was somewhat above the normal; over the middle section of the steamer lanes, about normal, and over the eastern section, somewhat below.

The positive pressure departure at Horta, and the negative departures at stations on the British Isles, as shown on Table 1, indicate that both the North Atlantic HIGH and Icelandic LOW were well developed, although judging from vessel reports, the conditions over the area between these two centers of action were not abnormal.

The month was unusually free from fog over the Grand Banks, where it was reported on only 4 days, in place of the usual 10 to 15 days. Fog occurred on 3 days off the American coast, between the thirty-fifth and fortieth parallels; from 2 to 5 days over the steamer lanes, east of the thirtieth meridian; on 1 day in the eastern section of the Gulf of Mexico; the middle section of the steamer lanes was practically clear.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level, 8 a. m. (seventy-fifth meridian). North Atlantic Ocean, December, 1930.*

Stations	Average Pressure	Departure	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Julianehaab, Greenland	29.47	(1)	30.12	21st	28.86	3d.
Belle Isle, Newfoundland	29.74	[2]+0.04	30.54	5th	28.92	14th.
Halifax, Nova Scotia	29.95	[2] 0.00	30.72	3d	29.30	9th.
Nantucket	29.99	[3]−0.03	30.66	3d	29.48	27th.
Hatteras	30.06	[3]−0.06	30.60	25th	29.68	27th.
Key West	30.07	[3]−0.02	30.32	24th	29.88	22d.
New Orleans	30.17	[3]+0.02	30.38	24th	29.82	5th.
Cape Gracias, Nicaragua	29.92	[3]−0.06	29.98	10th[4]	29.80	22d.
Turks Island	30.05	[3]−0.02	30.24	31st	29.88	8th.
Bermuda	30.00	[3]−0.12	30.46	26th	29.54	6th.
Horta, Azores	30.36	[3]+0.25	30.52	2d	30.06	31st.
Lerwick, Shetland Islands	29.66	[3]−0.06	30.36	22d	28.94	13th.
Valencia, Ireland	29.85	[3]−0.09	30.64	21st	28.84	30th.
London	29.87	[3]−0.15	30.59	19th	28.86	31st.

[1] No normal available.
[2] From normals shown on Hydrographic Office Pilot Charts, based on observations at Greenwich mean noon, or 7 a. m., seventy-fifth meridian time.
[3] From normals based on 8 a. m. observations.
[4] And on other dates.

On the 1st there was a stiff norther in the Gulf of Mexico—with barometric readings well over 30.30 inches on the coast of Texas—that was responsible for the wreck of the Mexican S. S. *San Francisco*, the passengers and crew being rescued by the Italian S. S. *Sangro*, Captain Staulese.

On the same day there was a LOW over Labrador and gales prevailed between the fortieth and fiftieth parallels,

while moderate northwest gales also occurred in the vicinity of the Azores, accompanied by comparatively high barometric readings. On the 2d the conditions had changed but little since the previous day, although on the 2d and 3d the winds in the vicinity of the Azores had increased in force, while on the 2d the barometer at Horta read 30.52 inches.

On the 5th there was a comparatively shallow depression over the Bermudas that afterwards deepened, and on the 6th moderate to strong gales prevailed between the fifty-fifth and seventieth meridians.

On the 8th a LOW was central near Cape Race, Newfoundland, that moved slowly northeastward, reaching its greatest intensity on the 10th when central near 55° N., 57° W., where westerly winds of force 8 to 10 were reported from the southerly quadrants. Continuing in its easterly course this disturbance was off the coast of Europe on the 13th, the storm area then extending from the fiftieth to sixtieth parallels. On the 14th the center was over the North Sea, and while it had decreased in extent and intensity, moderate northwesterly gales were still reported by a number of vessels.

On the 14th Hatteras was near the center of a depression that developed into a severe disturbance as it moved northeastward. On the 15th the center was about 150 miles south of Sable Island, where a barometric reading of 28.98 inches was recorded, and strong to whole gales occurred as far south as the thirty-fifth parallel. On the 16th and 17th this LOW was over the middle and eastern sections of the northern steamer lanes, respectively, and on the latter date winds of hurricane force were encountered, as shown by reports in table of storms.

On the 18th northerly gales were reported from a limited area between the seventieth meridian and American coast, between Hatteras and Nantucket, and on the same day there was also a moderate disturbance central near 50° N., 25° W.

A LOW that was central near 42° N., 52° W., on the 19th moved rapidly northeastward, increasing in intensity and resulting in moderate to strong gales over the middle section of the steamer lanes from the 20th to 22d. This was followed by another LOW that on the 23d was central about 300 miles east of the Virginia Capes, with winds of force 7 near the center; by the 24th the storm area had increased in intensity and extent, and by the 25th strong to whole gales prevailed between the thirty-fifth and fortieth parallels and the fifty-fifth and sixty-fifth meridians.

Charts VIII to XI cover the period from the 26th to 29th, inclusive, and show the progress of this disturbance, as well as that off the coast of Europe.

On the 31st a LOW, central about 250 miles south of Newfoundland, was responsible for heavy weather between that locality and the Bermudas, and on the same day a second disturbance was central near 48° N., 30° W., with westerly winds of nearly hurricane force in the southerly quadrants.

OCEAN GALES AND STORMS, DECEMBER, 1930

Vessel	Voyage		Position at time of lowest barometer		Gale began	Time of lowest barometer	Gale ended	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Highest force of wind and direction	Shifts of wind near time of lowest barometer
	From—	To—	Latitude	Longitude									
NORTH ATLANTIC OCEAN			° ′	° ′				*Inches*					
Iowan, Am. S. S.	New York	Canal Zone	35 42 N	74 28 W	Dec. 1	2 a, 1	Dec. 1	29.88	S	S, 7	SW	S, 10	Steady.
Lucia C, Ital. S. S.	Baltimore	Gibraltar	37 17 N	19 58 W	Dec. 1	11 p, 2	Dec. 4	29.97	NW	NNE, 10	NNE	NNE, 11	
Tiger, Nor. S. S.	Oslo	New York	45 45 N	54 24 W	Dec. 2	Noon, 2	Dec. 3	29.54	SSW	SW, 9	NW	W, 10	SSW-NW.
Saccarappa, Am. S. S.	Bremen	Charleston	34 40 N	62 00 W	Dec. 6	10 p, 6	Dec. 8	29.37	SE	SE, 8	NW	—, 10	SE-SW.
Winnebago, Br. S. S.	Manchester	Philadelphia	48 10 N	50 30 W	Dec. 9	4 p, 9	Dec. 11	28.79	SSW	SW, 9	W	SW, 10	SSW-W.
Sagaporack, Am. S. S.	Copenhagen	Portland, Me.	53 53 N	38 00 W	Dec. 6	—, 10	Dec. 15	28.90	WNW	WSW, 7	NNW	—, 10	SW-W.
Maine, Dan. S. S.	Newcastle	do	58 20 N	15 30 W	Dec. 12	3 a, 13	Dec. 18	28.49	WNW	WNW, 9	NW	—, 12	WSW-WNW.
Barendrecht, Du. S. S.	Charleston	London	35 55 N	72 35 W	Dec. 14	11 a, 14	Dec. 16	29.30	ESE	NE, 10	N	NW, 12	ESE-NW.
Victolite, Br. M. S.	Halifax	Cartagena	37 40 N	64 34 W	Dec. 14	8 p, 14	Dec. 15	28.50	E	N, 5	NW	NW, 10	N-NW.
Ponce, Am. S. S.	San Juan	New York	36 10 N	72 30 W	Dec. 14	—, 15	Dec. 15	28.98	SE	NW, 12	NW	—, 12	SE-NW.
Pennsylvania, Du. S. S.	Newport News.	Rotterdam	45 40 N	44 30 W	Dec. 15	2 p, 15	Dec. 16	29.31	SE	SSE, 8	WSW	SW, 10	S-SSW.
Tiger, Nor. S. S.	New York	Bergen	53 01 N	41 30 W	Dec. 15	Noon, 16	Dec. 17	28.47	SE	SSW, 10	WSW	SSW, 12	SSE-SSW.
Minnesotan, Am. S. S.	do	Canal Zone	36 08 N	73 40 W	Dec. 17	9 p, 17	Dec. 18	29.64	E	SE, 10	NNW	SE, 10	
Bergensfjord, Nor. S. S.	Bergen	New York	56 47 N	30 00 W	Dec. 16	4 a, 17	Dec. 17	28.85	SSW	SW, —	WSW	SW, 11	SSW-WSW.
Barendrecht, Du. S. S.	Charleston	London	40 22 N	53 14 W	Dec. 19	10 a, 19	Dec. 19	29.54	S	W, 7	NNW	N, 12	S-W-N
Cingalese Prince, Br. M. S.	Port Said	Boston	42 30 N	45 54 W	Dec. 19	9 p, 19	Dec. 20	29.71	SE	SW, 10	NW	SW, 10	SW-WSW.
Sarcoxie, Am. S. S.	New York	Havre	44 30 N	55 11 W	Dec. 20	—, 21	Dec. 21	29.87	SE	S, 8	S	SSE, 10	SE-S.
Maine, Dan. S. S.	Newcastle	Portland, Me.	51 10 N	44 10 W	Dec. 22	8 a, 22	Dec. 23	29.68	NW	NW, 9	NW	—, 11	
Dordrecht, Du. S. S.	Bay Town	Manchester	33 54 N	74 39 W	Dec. 22	Mdt, 22	Dec. 25	29.90	NW	NW, 9	NNW	NW, 10	
Nubian, Br. S. S.	Liverpool	Boston	53 00 N	29 00 W	Dec. 25	4 a, 25	Dec. 25	29.16	WSW	—, 10	W	—, 12	WSW-W.
Tulsa, Am. S. S.	Savannah	Liverpool	48 06 N	32 57 W	Dec. 26	6 a, 26	Dec. 26	29.02	SW	WSW, 12	WNW	WSW, 12	WSW-WNW.
West Kedron, Am. S. S.	Africa	Philadelphia	36 32 N	64 57 W	Dec. 27	10 p, 27	Dec. 27	29.28	S	SW, 10	NW	WNW, 11	W-SW.
Persephone, Danz. S. S.	Baytown	Denmark	48 00 N	41 28 W	Dec. 27	7 p, 27	Dec. 28	29.76	WSW	W, 11	NNW	NNW, 11	WSW-NNW.
Gonzenheim, Ger. S. S.	Galveston	Bremen	41 34 N	48 24 W	Dec. 27	5 p, 28	Dec. 29	29.32	S	SW, 7	W	S, 12	
Nubian, Br. S. S.	Liverpool	Boston	47 30 N	46 40 W	Dec. 28	4 a, 29	Dec. 29	29.14	WSW	—, 10	WSW	—, 12	Steady.
Ensley, City Am. S. S.	do	Baltimore	36 31 N	71 39 W	Dec. 30	Noon, 30	Dec. 31	29.46	W	W, 6	NW	WNW, 10	W-WNW.
Quaker City, Am. S. S.	Hull	Philadelphia	51 32 N	1 50 E	Dec. 30	2 p, 30	Dec. 31	29.19	SSW	—, 7	N	W, 12	
Coldwater, Am. S. S.	Antwerp	Charleston	33 10 N	59 15 W	Dec. 27	6 a, 31	Dec. 31	29.59	S	S, 8	NW	—, 11	S-W.
Emile Francqui, Belg. S. S.	do	New York	48 20 N	29 45 W	Dec. 31	4 a, 31	Dec. 31	28.91	W	W, 5	W	W, 11	
Samland, Belg. S. S.	do	do	43 15 N	50 03 W	Dec. 31	10 p, 31	Jan. 1	28.90	WNW	WNW, 9	WNW	NW, 11	WNW-NW.

Vessel	Voyage		Position at time of lowest barometer		Gale began	Time of lowest barometer	Gale ended	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Highest force of wind and direction	Shifts of wind near time of lowest barometer
	From—	To—	Latitude	Longitude									
NORTH PACIFIC OCEAN			° ′	° ′				*Inches*					
Silverbelle, Br. M. S.	Manila	San Francisco	36 50 N	173 45 W	Dec. 1	8 a, 1	Dec. 1	29.86	NW	WNW, 7	NW	NW, 9	Steady.
Oregon, Am. S. S.	Otaru	do	46 56 N	151 54 W	Dec. 1	2 p, 2	Dec. 3	28.65	E	W, 5	SW	SE, 9	E-S-SW.
Admiral Farragut, Am. S. S.	Kodiak	Seattle	58 00 N	151 00 W	Dec. 2	—, 3	Dec. 3	28.78	NE	NNE, 9	NE	NNE, 9	NE-NNE.
Hakubasan Maru, Jap. M. S.	Yokohama	San Francisco	46 50 N	155 00 W	Dec. 2	8 a, 2	Dec. 3	28.76	NW	S, 6	S	W, 9	NE-S-NE.
Michigan, Am. S. S.	Portland, Oreg.	The Orient	47 10 N	164 00 E	Dec. 2	2 p, 2	Dec. 5	29.26	WSW	WSW, 8	W	W, 9	WSW-W.
Everett, Am. S. S.	Zamboanga, P. I.	San Francisco	45 07 N	171 30 E	Dec. 4	11 p, 4	Dec. 6	29.35	SW	NW, 8	NW	W, 9	SW-NW.
Oregon, Am. S. S.	Otaru	do	45 14 N	141 30 W	Dec. 4	8 p, 4	Dec. 5	29.21	S	S, 9	W	W, 9	S-SW-W.
Olympia, Am. S. S.	do	do	42 25 N	176 30 W	Dec. 4	2 a, 5	Dec. 6	29.15	W	W, 8	W	W, 10	Steady.
Wisconsin, Am. S. S.	Portland, Oreg.	Shanghai	49 00 N	169 00 E	Dec. 4	4 a, 4	Dec. 7	28.78	NNW	NNW, 7	NW	NW, 9	N-W-NW.
Stuart Dollar, Am S. S.	Tabaco, P. I.	Los Angeles	37 15 N	168 25 E	Dec. 5	1 p, 5	Dec. 6	29.51	NW	NW, 7	NW	NW, 9	NW-NNW.
Tamaha, Br. S. S.	Shanghai	San Pedro	38 38 N	172 50 W	Dec. 5	10 p, 7	Dec. 8	29.11	W	W, 12	NW	W, 12	SW-W-WNW.
Mojave, Am S. S.	San Pedro	Nagasaki	30 14 N	158 26 E	Dec. 6	10 p, 6	Dec. 7	29.73	SE	SE, 8	SW	SW, 9	SW-W.
Maliko, Am S. S.	Puget Sound	Hawaiian Islands.	35 30 N	143 00 W	Dec. 6	10 p, 10	Dec. 12	29.68	SSE	SSW, 7	W	W, 10	SSW-SW.
Stuart Dollar, Am. S. S.	Tabaco	Los Angeles	40 42 N	170 30 W	Dec. 7	Mdt. 8	Dec. 8	28.43	SE	WSW, 7	NW	NW, 11	SSW-WSW.
Illinois, Am. S. S.	Hong Kong	San Francisco	41 15 N	155 20 E	Dec. 10	2 a, 11	Dec. 11	29.09	ENE	NE, 9	NNW	N, 10	NE-N.
Pres. Taft, Am. S. S.	Yokohama	do	34 45 N	153 05 E	Dec. 10	4 p, 10	Dec. 12	29.40	SSW	SW, 7	NW	W, 9	SSE-SW.
Columbia Maru, Jap. M. S.	do	Seattle	41 30 N	166 45 E	Dec. 10	6 p, 11	Dec. 12	28.92	SE	NE, 4	N	N, 9	SE-S-N.
Shiraha Maru, Jap. S. S.	Miike	Coos Bay	49 54 N	151 42 W	Dec. 10	Noon, 11	Dec. 15	29.10	NNW	WNW, 6	W	SW, 10	NW-SW-WSW.
Pres. Jackson, Am. S. S.	Yokohama	Seattle	49 40 N	133 30 W	Dec. 11	5 p, 11	Dec. 11	29.30	SE	SE	SE	SE, 10	Steady.
Dorothy Alexander, Am. S. S.	Seattle	San Diego	43 23 N	124 42 W	Dec. 12	2 a, 12	Dec. 12	29.65	SE	SE, 7	SW	SE, 9	SE-SSE-S.
Steel Trader, Am. S. S.	Honolulu	Yohohama	29 45 N	151 40 E	Dec. 13	—, 13	Dec. 13	29.79	W	W, 9	W	W, 9	W-N.
Illinois, Am. S. S.	Hong Kong	San Francisco	44 04 N	168 56 E	Dec. 14	6 p, 14	Dec. 16	29.17	S	SW, 7	SW	W, 10	S-SW-W.
Protesilaus, Br. S. S.	Yokohama	Victoria	45 05 N	161 46 E	Dec. 14	Noon, 14	Dec. 16	29.66	NW	NW, 9	WNW	WNW, 10	SW-NW.
Columbia Maru, Jap. M. S	do	Seattle	49 25 N	159 30 W	Dec. 15	4 p, 16	Dec. 16	29.35	SSW	SW, 10	WSW	SW, 10	SW-SSW-SW.
Steel Trader, Am. S. S.	Honolulu	Yokohama	31 55 N	142 47 E	Dec. 15	—, 15	Dec. 15	29.97	WNW	—, 9	WNW	WNW, 9	WNW-N.
Manoa, Am. S. S.	do	San Francisco	36 15 B	127 05 W	Dec. 16	8 a, 17	Dec. 17	30.32	NNW	NNW, 8	NNW	NNW, 9	Steady.
Columbian, Am. S. S.	Los Angeles	Balboa	10 05 N	86 32 W	Dec. 16	—, 17	Dec. 17	29.91	ENE	NE, 8	NE	NE, 8	E-NNE-NE.
City of Elwood, Am. S. S.	Shanghai	San Pedro	47 06 N	171 00 W	Dec. 17	11 p, 18	Dec. 19	29.04	SE	WSW, 10	W	SW, 10	SSW-W.
Pres. McKinley, Am. S. S.	Yokohama	Seattle	42 20 N	153 55 E	Dec. 19	6 a, 20	Dec. 20	29.22	WSW	SE, 9	WSW	SE, 9	SE-SSE.
Japan Arrow, Am. S. S.	San Pedro	Balboa	15 38 N	98 32 W	Dec. 23	1 a, 24	Dec. 24	29.89	NE	NE, 9	NW	NNE, 10	NE-NNE.
Mojave, Am. S. S.	Yokohama	San Pedro	38 24 N	171 27 E	Dec. 23	6 a, 25	Dec. 29	29.47	NW	S, 8	WNW	WNW, 11	NW-S-WNW.
Kansan, Am. S. S.	Los Angeles	Balboa	9 27 N	87 01 W	Dec. 23	4 p, 24	Dec. 24	29.72	E	NE, 8	NE	NE, 8	E-NE-S.
Ohioan, Am. S. S.	New York	Los Angeles	Gulf of Tehuantepec		Dec. 24	4 p, 24	Dec. 24	29.87	WNW	N, 10	NE	WNW, 11	NNW-N-NE.
City of San Francisco, Am. M. S.	San Pedro	Balboa	15 45 N	95 30 W	Dec. 29	2 p, 29	Dec. 29	29.98	N	NNE, 9	NW	NNE, 9	N-NNE-NW.
Golden River, Am. S. S.	Hong Kong	San Francisco	35 08 N	156 10 W	Dec. 30	2 p, 30	Dec. 30	29.89	WNW	WNW, 9	WNW	WNW, 10	Steady.
Diana Dollar, Am. S. S.	Tabaco	Los Angeles	41 09 N	174 40 W	Dec. 30	Noon, 30	Jan. 4	29.24	SW	SSE, 10	W	W, 10	SW-W-SSE.
SOUTH ATLANTIC OCEAN													
Brookwood, Br. S. S.	Port Natal	Swansea	33 30 S	27 50 E	Dec. 2	2 a, 2	Dec. 2	29.73	SW	SW, 8	WSW	SW, 9	ENE-S-SW.

NORTH PACIFIC OCEAN

By WILLIS E. HURD

Atmospheric pressure.—A considerable fall in atmospheric pressure occurred over the upper waters of the North Pacific Ocean during December. The result was one of the deepest cyclones of the Aleutian region for the month in recent years, the average pressures in the western part of the Gulf of Alaska and the eastern part of the Bering Sea being about 29.20 inches, or four-tenths of an inch below the December normal. The lowest readings of the month occurred on the 27th, the absolute minimum reported being 28.24 inches, at Dutch Harbor.

In American waters south of the central part of the British Columbia coast line, pressure for the most part was higher than the average, as it was also at the island stations of Midway and Honolulu. The North Pacific anticyclone as a whole occupied all except the upper region of the eastern part of the ocean, and the greater part of the sea elsewhere in middle latitudes between the American and Asiatic coasts.

The following table gives the principal barometric data for several island and coast stations in west longitudes, including Point Barrow on the Arctic Ocean.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level at indicated hours, North Pacific Ocean and adjacent waters, December, 1930*

Stations	Average pressure	Departure from normal	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Point Barrow [1]	29.86		30.32	1st	29.44	7th.
Dutch Harbor [1]	29.23	−0.35	29.96	23d	28.24	27th.
St. Paul [1 2]	29.20	−0.41	29.92	23d	28.54	27th.
Kodiak [1]	29.19	−0.39	29.58	10th	28.46	6th.
Midway Island [1]	30.11	+0.07	30.36	29th	29.84	12th.
Honolulu [3]	30.08	+0.07	30.26	30th	29.87	14th.
Juneau [3]	29.67	−0.12	30.16	27th	29.13	15th.
Tatoosh Island [3 4]	30.13	+0.16	30.46	16th	29.54	31st.
San Francisco [3 4]	30.17	+0.06	30.44	28th	29.92	31st.
San Diego [3 4]	30.08	+0.04	30.29	28th	29.91	2d.

[1] P. m. observations only.
[2] For 30 days.
[3] A. m. and p. m. observations.
[4] Corrected to 24-hour mean.

Cyclones and gales.—Owing to the unusually steep slope of barometric pressure existing in December between the Aleutian area, on the one hand, and the lower central part of the ocean, on the other, stormy weather was frequently encountered along the upper and middle trans-Pacific routes throughout the month. In general, the storminess in west longitudes was more the result of the activities of the fluctuating disturbance known as the Aleutian LOW, than of traveling cyclones, few storms moving across from the Asiatic region. West of the one hundred and eightieth meridian gales resulted from both progressive and fluctuating cyclones.

From the standpoint of high winds, the severest extratropical cyclone of the month was one that gathered in the southwestern part of the Aleutian storm area on the 7th and caused hurricane velocities near 39° N., 173° W. On the 8th the maximum force of the winds, as indicated by reports, had diminished to 11 near the same position, although the barometer had dropped considerably, the minimum reading on this date being 28.43 inches, as obtained on the American steamer *Stuart Dollar*, in about 40° N., 170° W. Thereafter the storm lessened in intensity, as it entered and for several days lay over the Gulf of Alaska.

The succeeding storm of next highest wind violence developed intensity southeast of the Kuril Islands about the 22d, but may have originated as a Siberian depression at an earlier date. From the 23d to 26th it caused scattered westerly gales of force 10 to 11 between latitudes 35° and 50° N., and longitudes 160° E. and 180°. By the 27th it was central over the eastern Aleutians, where it gave the lowest barometric pressures of the month at Dutch Harbor and St. Paul. At this time, however, the wind intensity seems to have decreased to moderate to strong gales over a large area. During the 28th the storm center began filling in, and by the 29th, still central near the western extremity of the Peninsula of Alaska, it had become comparatively shallow and of little violence.

For the upper two-thirds of the ocean the month may well be characterized as a stormy one. In addition to the heavy gales already referred to, winds of force 10 occurred on several days in scattered localities, and of force 9, on about 20 days of the month, covering most parts of the ocean north of the twenty-fifth parallel. Strong to whole cyclonic gales occurred off the Washington and Oregon coasts on the 11th and 12th, and an anticyclonic gale of force 9, off the central California coast on the 17th.

Northeast monsoon gales blew in Taiwan Channel on the 1st to 5th, and were strong in the neighborhood on other dates.

In the Gulf of Tehuantepec fresh to strong northers occurred on the 1st, 2d, 7th, 8th, 12th, 23d, and 29th, and in addition attained a maximum force of 11 on the 24th. Off the lower Central American coast moderate to strong northeasters blew on the 17th and 24th.

The prevailing wind at Honolulu continued from the east, with a maximum velocity of 30 miles from the same direction on the 22d. Velocities of force 8 were reported some 200 to 300 miles northwest of Honolulu on the 14th and 15th.

Fog was of little consequence over the North Pacific during December. There were no reports of its occurrence west of the one hundred and eightieth meridian, and very few for any other part of the ocean, except off the California coast, where it was encountered on six days between the 1st and the 12th.

CLIMATOLOGICAL TABLES

[For description of tables and charts, see REVIEW, January, 1930, p. 37]

CONDENSED CLIMATOLOGICAL SUMMARY

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, December, 1930

Section	Temperature								Precipitation					
			Monthly extremes								Greatest monthly		Least monthly	
	Section average	Departure from the normal	Station	Highest	Date	Station	Lowest	Date	Section average	Departure from the normal	Station	Amount	Station	Amount
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	43.8	−3.5	Brewton	75	11	Valley Head	18	23	2.84	−2.01	Silver Hill	5.90	Elba	1.25
Arizona	42.4	−1.8	Granite Reef Dam	87	12	Snowflake	−13	28	0.25	−1.01	Rucker Canyon	1.55	44 stations	0.00
Arkansas	40.6	−1.9	Hope	83	11	Dutton	9	[1] 22	2.58	−1.47	Warren	5.31	Mammoth Springs	0.95
California	44.1	−0.9	Santa Ana	85	8	Madeline	−5	29	0.47	−3.77	Cummings	5.99	101 stations	0.00
Colorado	22.4	−2.1	Las Animas	66	2	Sunbeam	−37	26	0.28	−0.81	La Veta Pass	1.40	9 stations	0.00
Florida	55.7	−3.9	Homestead	86	17	Jacksonville (No. 2)	22	24	4.17	+1.27	Brooksville	8.30	Coral Gables	0.69
Georgia	43.8	−3.8	Fargo	76	1	Clayton	10	18	3.35	−0.91	Clayton	6.75	2 stations	2.16
Idaho	18.9	−6.1	Glenns Ferry	51	11	Felt	−29	25	0.69	−1.30	Pete King Ranger Station.	2.83	3 stations	0.00
Illinois	31.3	+0.8	Sparta	70	9	Mount Carroll	−9	24	0.71	−1.53	Mount Carmel	2.16	Danville	0.15
Indiana	31.4	−0.7	Princeton	63	9	Laporte	−6	24	1.10	−1.80	Salem	2.51	Fowler	0.09
Iowa	26.7	+2.6	Albia	65	9	Olin	−10	16	0.57	−0.57	Washington	1.69	Lake Park (near)	T.
Kansas	33.6	+1.9	Atchison	68	10	Ulysses	1	[1] 20	0.38	−0.52	Sedan	1.94	3 stations	T.
Kentucky	35.4	−2.1	Earlington	69	11	Farmers	2	24	2.21	−1.82	Harlan	3.47	Franklin	0.75
Louisiana	48.7	−3.6	4 stations	76	11	2 stations	20	17	3.90	−1.35	Leesville	7.06	New Orleans (No. 3)	1.55
Maryland-Delaware	33.4	−1.7	Millsboro, Del	62	12	Oakland, Md	−17	25	2.60	−0.69	Oakland, Md	4.35	Millsboro, Del	1.59
Michigan	25.7	+0.8	Howard City	58	11	Vanderbilt	−18	15	1.00	−1.15	Deer Park	3.96	Twin Falls	0.15
Minnesota	19.7	+5.3	Worthington	61	9	2 stations	−25	3	0.23	−0.58	Gonvick	3.19	6 stations	T.
Mississippi	44.5	−3.5	Leakesville	75	5	5 stations	20	[1] 17	3.58	−1.53	Fayette	5.71	Fruitland Park	1.80
Missouri	34.2	+0.3	Greenville	70	9	Seymour	2	17	1.23	−0.84	Dean	3.78	2 stations	0.18
Montana	26.7	+4.7	Lewistown	66	8	Hebgen Dam	−25	25	0.23	−0.72	Heron	2.01	17 stations	0.00
Nebraska	29.8	+3.9	3 stations	68	[1] 9	Purdum	1	21	0.21	−0.49	Halsey	0.75	3 stations	0.00
Nevada	28.0	−4.2	Logandale	71	9	Owyhee	−21	21	0.07	−0.82	Arthur	0.69	25 stations	0.00
New England	27.2	+0.6	Springfield, Mass	64	1	Bethlehem, N. H	−18	16	2.08	−1.26	Nantucket, Mass	5.14	Bennington, Vt	0.52
New Jersey	33.0	+0.4	2 stations	60	1	Layton	−5	25	2.67	−1.35	Belvidere	3.92	Bridgeton	1.58
New Mexico	30.2	−2.9	Rodeo	69	[1] 10	Red River	−25	[1] 22	0.37	−0.35	Cloverdale	2.38	10 stations	0.00
New York	27.9	+1.3	Cairo	58	1	Stillwater Reservoir	−19	16	1.86	−1.12	Cutchogue	4.96	Chazy	0.49
North Carolina	38.3	−4.1	5 stations	70	[1] 1	Boone	−4	21	4.44	+0.43	Manteo	8.63	Marshall	1.20
North Dakota	19.9	+6.9	Hettinger	53	8	Willow City	−30	1	0.19	−0.35	Pembina	0.90	5 stations	0.00
Ohio	30.9	−0.3	McArthur	60	1	Medina	−5	2	1.19	−1.64	Marietta (No. 1)	2.51	Van Wert	0.40
Oklahoma	39.9	+0.7	Idabel	73	11	Boise City	8	22	2.01	+0.52	Eufaula	4.42	Hooker	0.19
Oregon	32.5	−1.3	Hillcrest Orchard	65	2	Blitzen	−15	27	2.03	−2.47	Willow Creek	8.44	Juniper Ranch	0.03
Pennsylvania	30.0	−1.1	York	59	10	Somerset	−15	25	2.29	−0.94	Warren	4.06	Zelienople	0.82
South Carolina	41.5	−4.9	Garnett	74	11	2 stations	10	[1] 18	3.84	+0.31	Caesars Head	5.93	Aiken	2.04
South Dakota	26.9	+6.9	Spearfish	67	8	Milbank	−11	1	0.17	−0.43	Hardy Ranger Station.	1.97	5 stations	0.00
Tennessee	37.4	−3.1	3 stations	68	4	Rugby	1	24	3.09	−1.41	Hohenwald	5.58	Altamont	0.73
Texas	46.0	−3.8	2 stations	85	[1] 11	Muleshoe	−1	22	1.93	−0.23	Goose Creek	5.57	Fowlerton	0.00
Utah	19.2	−6.8	Springdale	62	7	Woodruff	−23	27	0.23	−1.02	Silver Lake	1.27	21 stations	0.00
Virginia	35.1	−3.1	Christchurch	74	1	Burkes Garden	−7	25	2.97	−0.28	Danville	4.72	Quantico	1.41
Washington	32.2	+0.3	2 stations	61	[1] 2	Bumping Lake	−5	[1] 26	2.37	−3.39	Forks	11.26	Oroville	0.11
West Virginia	30.9	−2.4	Charleston	66	3	Marlinton	−14	25	2.81	−0.70	Pickens	6.59	Upper Tract	0.76
Wisconsin	22.3	+2.1	New London	57	9	Prentice	−18	2	0.42	−0.88	Racine	1.03	2 stations	0.10
Wyoming	21.4	+0.8	2 stations	62	[1] 8	Dixon	−34	27	0.26	−0.58	Bechler River	1.27	6 stations	0.00
Alaska (Nov.)	9.6	−3.0	do	58	[1] 1	Eagle	−52	[1] 29	3.61	+1.19	Latouche	27.88	Barrow	0.01
Hawaii	70.8	+1.0	4 stations	88	[1] 2	Volcano Observatory	47	31	4.07	−5.71	Puu Kukui (upper)	16.00	3 stations	0.00
Porto Rico	75.8	+1.2	San German	94	2	Guineo Reservoir	46	5	4.23	−0.27	Barros	9.40	Central Aguirre	0.34

[1] Other dates also.

TABLE 1.—*Climatological data for Weather Bureau stations, December, 1930*

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with .01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles								0–10	In.	In.
New England							30.2	+0.8										76	2.39	−1.0										6.8		
Eastport	76	67	85	29.89	29.97	−0.01	27.2	+0.9	54	1	34	−2	16	21	30	25	22	78	2.42	−1.3	15	8,076	nw.	43	sw.	1	4	4	23	8.4	10.7	6.7
Greenville, Me	1,070	6	....	28.78	29.99	....	19.9	....	45	1	27	−10	16	13	26	....	....	....	2.74	....	....	4,681	se.	....	....	....	4	10	17	....	24.5	....
Portland, Me	103	82	117	29.90	30.03	.00	28.3	+0.7	53	1	35	4	16	22	26	25	19	69	1.93	−2.0	8	5,470	n.	29	nw.	1	11	5	15	6.0	10.2	7.0
Concord	289	70	79	29.68	30.01	−.05	26.8	0.0	43	1	35	−1	25	19	35	....	....	....	1.14	−2.0	10	3,110	nw.	19	nw.	13	10	5	16	6.2	12.0	8.6
Burlington	403	11	48	29.56	30.03	−.02	24.6	+0.2	41	9	30	−7	16	19	29	....	....	....	0.82	−1.1	11	7,152	s.	36	s.	3	0	6	25	8.8	8.7	1.8
Northfield	876	12	60	....	30.04	−.01	23.0	+2.6	50	1	32	−11	16	14	42	....	....	87	0.85	−1.6	11	3,879	s.	21	n.	1	0	8	23	8.6	8.7	3.0
Boston	125	106	165	29.87	30.01	−.04	33.2	+0.7	58	1	40	4	16	27	31	30	25	72	2.99	−0.5	8	5,852	nw.	26	nw.	1	12	4	15	5.9	7.7	1.0
Nantucket	12	14	90	29.97	29.98	−.07	36.4	+0.6	56	1	42	11	16	31	24	34	31	81	5.14	+1.4	16	10,279	w.	67	ne.	27	8	3	20	7.2	0.4	0.0
Block Island	26	11	46	29.97	30.00	−.06	35.6	−0.4	56	1	40	10	16	31	27	33	29	76	3.53	−0.3	11	13,312	w.	54	nw.	2	11	4	16	6.3	2.1	0.1
Providence	160	215	251	29.84	30.02	−.04	32.7	+1.1	57	1	39	6	16	27	30	29	24	70	2.67	−0.7	9	7,574	nw.	42	nw.	2	12	3	16	5.9	6.5	0.3
Hartford	159	122	....	29.86	30.04	−.03	31.7	+1.9	56	1	38	2	16	25	33	....	....	....	2.35	−1.6	9	....	sw.	....	....	....	11	3	17	6.2	9.5	3.6
New Haven	106	74	153	29.92	30.04	−.03	32.7	+0.2	55	1	38	6	16	27	34	29	24	71	2.42	−1.6	8	6,167	n.	33	n.	27	14	1	16	5.7	11.0	3.8
Middle Atlantic States							34.6	−1.1										73	2.32	−1.0										6.6		
Albany	97	107	115	29.95	30.06	−.02	30.2	+1.7	50	1	36	3	16	24	32	27	21	70	0.69	−1.9	12	4,415	s.	21	s.	3	8	7	16	6.5	4.7	1.8
Binghamton	871	10	84	29.09	30.05	−.04	28.2	0.0	43	12	34	4	17	22	29	....	....	....	1.70	−0.6	15	3,838	nw.	17	nw.	13	0	4	27	8.9	11.7	5.5
New York	314	414	454	29.70	30.06	−.03	35.0	0.0	56	1	41	9	16	29	30	31	24	67	2.65	−1.0	12	10,530	nw.	55	nw.	2	6	7	18	6.8	4.2	0.1
Bellefonte	1,050	5	36	28.92	30.07	....	26.8	....	43	9	34	−2	25	20	34	25	22	82	2.84	....	7	....	w.	....	....	....	2	4	25	8.6	10.3	4.5
Harrisburg	374	94	104	29.70	30.12	.00	32.2	−0.5	51	9	38	12	16	26	29	28	22	67	2.27	−0.8	5	4,844	w.	26	sw.	9	5	9	17	7.2	3.7	T.
Philadelphia	114	123	367	29.95	30.08	−.03	36.6	+0.3	57	1	42	14	16	32	31	32	25	63	2.50	−0.9	8	9,252	nw.	39	nw.	1	8	10	13	6.2	2.1	0.0
Reading	325	81	98	29.72	30.09	....	33.4	+1.2	51	9	39	11	16	28	28	30	24	71	2.61	−1.0	9	4,250	nw.	23	nw.	1	7	9	15	7.0	2.0	T.
Scranton	805	111	119	29.18	30.08	−.02	29.9	−0.8	50	1	36	7	17	24	33	27	23	78	2.04	−1.0	15	4,301	sw.	20	nw.	1	3	10	18	7.4	17.6	5.5
Atlantic City	52	37	172	30.00	30.06	−.04	36.4	0.0	55	1	42	14	16	31	27	33	29	76	2.27	−1.7	12	10,774	w.	42	ne.	27	11	5	15	6.0	2.6	0.0
Cape May	17	13	49	....	....	....	36.6	−1.4	56	12	43	15	16	30	29	34	31	84	1.97	−1.8	11	....	nw.	....	....	....	8	8	15	....	3.4	0.0
Sandy Hook	22	10	55	30.02	30.04	....	34.9	....	55	1	39	13	16	30	28	32	28	76	2.09	−2.0	12	11,211	w.	42	ne.	27	9	4	18	6.7	0.8	0.0
Trenton	190	159	183	29.85	30.07	....	33.7	−0.7	57	1	40	11	16	27	35	30	25	71	2.38	−1.0	7	7,056	nw.	35	nw.	1	9	8	14	6.3	3.8	0.0
Baltimore	123	100	215	29.95	30.09	−.04	37.0	−0.2	55	9	43	16	16	31	30	32	26	68	1.95	−1.4	7	7,067	sw.	41	nw.	1	7	10	14	6.3	1.6	0.0
Washington	112	62	85	29.98	30.11	−.02	35.7	−0.9	56	1	42	15	16	29	34	31	24	67	2.04	−1.3	7	4,524	nw.	30	nw.	1	9	7	15	6.1	2.8	0.0
Cape Henry	18	8	54	30.05	30.07	....	40.7	−3.0	62	11	46	21	25	35	24	37	34	80	3.39	0.0	10	9,769	nw.	45	n.	2	8	9	14	6.1	2.5	0.0
Lynchburg	681	153	188	29.34	30.11	−.03	36.5	−3.0	65	10	44	14	25	29	32	32	26	66	2.80	−0.5	6	4,678	w.	35	nw.	27	12	10	9	5.4	7.8	T.
Norfolk	91	170	205	29.99	30.09	−.04	40.4	−2.7	63	10	47	21	16	34	24	36	32	74	3.02	−0.3	9	8,090	n.	39	nw.	27	9	8	14	6.0	2.7	0.0
Richmond	144	11	52	29.95	30.12	−.02	36.8	−3.0	62	10	45	16	16	29	32	32	28	76	2.48	−0.8	7	4,946	ne.	26	nw.	30	12	6	13	5.5	6.0	0.0
Wytheville	2,304	49	55	27.66	30.14	−.01	29.7	−5.6	55	3	37	1	25	22	37	27	23	79	2.88	0.0	8	4,900	w.	23	nw.	1	8	8	15	6.4	18.1	2.4
South Atlantic States							43.2	−4.2										76	3.51	+0.1										5.7		
Asheville	2,253	70	84	27.70	30.14	−.02	34.2	−3.6	56	10	42	13	21	26	30	30	26	75	2.45	−0.8	8	6,005	n.	28	nw.	27	9	6	16	6.2	9.2	T
Charlotte	779	55	62	29.26	30.12	−.04	38.6	−4.4	64	10	46	19	17	31	29	33	27	70	3.43	−0.4	6	3,474	ne.	15	w.	27	12	6	13	5.5	10.4	0.0
Greensboro	886	5	56	29.14	30.12	....	33.5	....	65	10	43	4	25	24	39	28	25	80	3.86	....	4	5,213	w.	28	nw.	27	14	2	15	5.6	14.3	0.4
Hatteras	11	5	50	30.04	30.05	−.08	45.9	−4.2	65	1	51	32	16	40	17	42	40	83	7.46	+3.2	12	10,294	n.	56	nw.	17	7	9	15	6.4	0.0	0.0
Raleigh	376	103	110	29.70	30.12	−.03	39.8	−3.2	66	10	48	21	17	32	26	34	29	71	3.68	+0.1	7	5,878	nw.	28	nw.	27	13	6	12	5.5	6.5	0.0
Wilmington	78	81	91	30.02	30.11	−.04	44.6	−4.5	68	10	53	26	25	36	28	40	35	76	4.55	+1.8	10	4,198	n.	21	sw.	1	10	7	14	5.7	T.	0.0
Charleston	48	11	92	30.06	30.10	−.05	47.2	−4.5	71	6	54	29	18	40	21	42	38	76	2.05	−0.7	10	7,045	n.	27	e.	16	9	6	16	6.0	0.0	0.0
Columbia, S. C	351	41	57	29.74	30.13	−.03	42.5	−4.7	66	11	50	24	17	35	28	37	32	73	2.74	−0.3	7	4,285	ne.	21	sw.	29	12	5	14	5.3	0.0	0.0
Due West	711	10	55	29.35	30.15	....	39.4	....	64	1	48	18	18	31	31	....	....	....	3.45	....	5	5,661	ne.	22	ne.	16	12	7	12	5.0	T.	T.
Greenville, S. C	1,039	139	146	28.98	30.10	....	39.5	−2.7	66	10	47	18	18	32	29	34	29	71	4.60	−0.2	6	4,983	ne.	23	ne.	5	14	3	14	4.8	14.4	T.
Augusta	182	62	77	29.92	30.12	−.04	44.0	−4.1	67	10	52	25	18	36	31	39	34	76	2.16	−1.1	7	3,389	nw.	18	nw.	23	13	4	14	5.3	0.2	0.0
Savannah	65	150	194	30.03	30.10	−.05	47.8	−4.6	70	11	55	30	18	40	24	42	38	77	2.35	−0.6	9	7,791	w.	30	nw.	26	11	3	17	5.9	0.0	0.0
Jacksonville	43	209	245	30.06	30.11	−.03	51.1	−5.2	70	6	58	34	18	44	23	46	43	79	3.11	+0.1	14	7,294	n.	45	se.	19	6	6	19	7.0	0.0	0.0
Florida Peninsula							62.8	−3.7										80	3.88	+2.1										6.8		
Key West	22	10	64	30.04	30.06	−.02	67.2	−3.1	81	19	72	50	24	62	16	62	60	82	4.26	+2.6	9	6,599	ne.	30	n.	23	8	7	16	6.5	0.0	0.0
Miami	25	124	168	30.04	30.07	−.05	64.4	−3.6	78	6	72	40	24	57	27	58	55	76	1.38	−0.3	9	7,146	n.	24	ne.	2	4	9	18	7.1	0.0	0.0
Tampa	35	79	197	30.06	30.10	−.02	56.7	−4.4	76	5	64	37	24	49	26	51	49	82	5.99	+3.9	13	7,505	nw.	28	nw.	23	6	8	17	6.7	0.0	0.0
Titusville[1]	44	5	....	30.04	30.09	....	57.8	....	80	6	66	35	24	49	29	....	....	....	4.38	....	13	....	nw.	....	....	....	5	15	6	6.7	0.0	0.0
East Gulf States							45.8	−3.7										75	2.88	−2.0										6.0		
Atlanta	1,173	190	216	28.86	30.13	−.03	39.6	−5.1	57	13	46	23	23	34	22	35	30	72	3.46	−1.2	10	7,763	nw.	29	nw.	30	11	5	15	5.7	T.	0.0
Macon	370	78	87	29.74	30.14	−.02	43.8	−3.7	69	11	52	26	21	36	30	38	33	72	2.71	−1.3	9	4,312	nw.	19	nw.	30	11	5	15	5.8	0.0	0.0
Thomasville	273	49	103	29.83	30.14	−.01	47.9	−4.6	70	10	55	32	23	40	25	42	39	79	2.34	−2.0	10	4,987	nw.	23	nw.	23	7	7	17	6.7	0.0	0.0
Apalachicola	36	11	51	30.09	30.13	....	51.1	....	69	12	58	36	24	45	22	47	43	81	3.35	−1.8	13	5,915	nw.	28	e.	16	10	6	15	6.2	0.0	0.0
Pensacola	56	149	185	30.09	30.15	.00	49.4	−4.6	66	5	55	30	23	44	21	45	42	78	3.37	−1.3	11	8,540	n.	38	se.	25	4	11	16	6.6	0.0	0.0
Anniston	741	9	57	29.35	30.17	+.01	41.1	−3.1	62	9	50	21	23	33	28	....	....	....	2.25	−2.8	8	3,670	nw.	21	se.	5	15	2	14	5.1	0.2	0.0
Birmingham	700	11	48	29.37	30.16	.00	43.2	−3.2	64	9	51	26	23	36	28	37	32	72	2.48	−2.7	11	4,282	nw.	34	se.	5	14	3	14	5.4	0.0	0.0
Mobile	57	125	161	30.09	30.15	.00	49.4	−2.8	70	5	57	30	23	42	22	45	42	82	3.12	−1.9	10	6,285	n.	33	se.	25	8	9	14	6.2	0.0	0.0
Montgomery	223	100	112	29.91	30.17	+.01	46.0	−3.4	67	11	53	29	23	39	26	40	35	70	2.48	−2.4	10	4,346	nw.	24	se.	26	10	6	15	5.8	0.0	0.0
Corinth	469	6	....	....	....	....	40.9	....	64	9	50	21	24	32	32	....	....	....	3.26	....	9	....	se.	....	....	....	7	11	13	....	1.5	0.0
Meridian	375	87	95	29.75	30.16	.00	44.8	−2.9	66	9	53	26	24	36	30	39	35	76	3.04	−2.2	9	3,514	nw.	20	w.	5	11	4	16	6.0	0.0	0.0
Vicksburg	247	65	73	29.90	30.19	+.04	46.0	−4.0	67	9	54	26	17	38	26	40	35	72	4.10	−1.2	10	4,080	n.	18	se.	4	11	4	16	6.0	0.0	0.0
New Orleans	53	76	84	30.10	30.16	+.03	52.6	−3.0	74	11	59	36	17	46	24	47	43	73	1.80	−3.0	10	4,460	nw.	23	e.	21	7	5	19	6.7	0.0	0.0
West Gulf States							48.3	−2.1										75	2.63	−0.4										5.8		
Shreveport	249	77	93	29.91	30.19	+.06	46.7	−2.4	67	9	54	27	17	39	24	43	39	80	3.89	−0.4	9	3,501	se.	8	w.	4	12	7	12	5.2	0.0	0 0
Bentonville	1,303	11	44	28.75	30.15	+.02	37.6	+0.1	63	9	46	17	17	30	29	....	....	....	2.58	....	....	2,922	nw.	16	s.	24	20	5	6	....	6.4	T
Fort Smith	457	79	94	29.67	30.16	+.03	42.0	−0.1	64	11	50	24	27	34	28	37	33	75	2.70	−0.1	5	4,643	e.	23	e.	14	12	11	8	4.8	T.	0.0
Little Rock	357	136	153	29.78	30.17	+.03	42.3	−1.9	64	9	50	25	16	35	24	37	30	67	2.28	−1.9	7	5,125	nw.	24	ne.	5	13	4	14	5.1	T.	0.0
Austin	605	136	148	29.53	30.18	....	49.1	−1.9	72	14	59	25	17	39	31	43	38	73	3.85	+1.2	7	5,003	n.	31	n.	15	10	9	12	5.7	0.0	0.0
Brownsville	57	83	100	30.09	30.15	....	58.2	−3.0	81	11	66	36	23	51	25	53	50	80	0.42	−1.1	9	5,802	nw.	28	se.	4	6	7	18	7.1	0.0	0.0
Corpus Christi	20	11	78	30.15	30.17	+.05	55.3	−2.7	77	11	62	33	23	49	26	51	48	79	0.71	−0.7	10	5,986	n.	30	n.	21	2	8	21	7.8	0.0	0.0
Dallas	512	220	227	29.62	30.18	....	45.6	....	67	1	54	24	22	38	28	....	....	....	1.95	−0.4	6	7,184	w.	36	w.	15	16	7	8	3.9	2.4	0.0
Fort Worth	670	106	114	29.45	30.18	+.06	47.4	−0.1	71	14	57	23	22	38	36	42	38	75	2.08	+0.2	6	4,502	nw.	26	s.	14	14	7	10	4.5	1.5	0.0
Galveston	54	106	114	30.13	30.19	+.07	52.8	−3.6	69	11	58	37	23	48	19	49	46	81	3.26	−0.5	8	6,857	nw.	30	nw.	15	6	8	17	6.9	0.0	0.0
Groesbeck	461	11	56	29.67	30.17	....	46.0	....	69	14	54	28	22	38	27	....	....	....	1.96	−1.2	8	5,807	n.	27	nw.	5	7	8	16	6.1	0.0	0.0
Houston	138	292	314	30.03	30.18	....	50.8	−3.6	71	14	58	33	23	44	21	....	....	....	4.07	−0.2	7	8,340	n.	32	nw.	28	8	8	15	6.5	0.0	0.0
Palestine	510	64	72	29.64	30.18	+.06	47.1	−2.8	67	14	55	26	22	39	28	42	37	75	3.08	−0.6	7	4,281	nw.	23	nw.	15	12	5	14	5.4	0.0	0.0
Port Arthur	34	58	66	30.13	30.17	....	51.5	....	73	11	58	34	23	45	21	....	....	....	5.12	−0.1	8	5,384	n.	28	sw.	4	10	4	17	6.5	0.0	0.0
San Antonio	693	242	301	29.43	30.16	+.05	51.0	−2.7	73	4	60	29	17	42	27	44	39	68	0.88	−0.7	8	6,514	n.	30	nw.	4	10	13	8	5.3	0.0	0.0
Taylor	571	38	51	29.59	30.20	+.09	48.1	−2.5	71	14	58	29	17	39	32	....	....	....	3.22	+0.9	8	4,558	nw.	24	nw.	15	12	6	13	5.5	0.0	0.0

[1] Precipitation complete. Otherwise for 26 days, 1–6 and 12–31.

TABLE 1.—*Climatological data for Weather Bureau stations, December, 1930*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with .01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
Ohio Valley and Tennessee	*Ft.*	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	*In.*	*In.*		*Miles*									*In.*	*In.*
							34.1	**−2.4**										**78**	**1.78**	**−1.7**										**6.9**		
Chattanooga	762	190	215	29.32	30.16	0.00	39.4	−3.9	61	9	46	23	24	33	28	35	30	71	3.66	−1.5	10	4,939	sw.	25	nw.	30	10	4	17	6.0	3.1	0.0
Knoxville	995	102	111	29.06	30.15	−.01	36.8	−3.5	61	4	43	20	31	31	26	34	31	80	2.30	−2.2	10	3,978	ne.	29	sw.	29	8	5	18	6.7	7.2	0.0
Memphis	399	76	97	29.73	30.16	+.01	41.0	−2.6	62	9	47	23	22	35	23	36	31	72	2.81	−1.7	11	5,136	sw.	24	nw.	23	10	9	12	5.5	0.7	0.0
Nashville	546	168	191	29.58	30.18	+.03	38.2	−2.8	62	9	45	20	24	31	29	34	29	74	2.09	−2.1	9	5,545	nw.	26	se.	5	10	9	12	5.7	3.3	0.0
Lexington	989	193	230	29.06	30.17	+.03	32.2	−3.6	54	4	38	12	2	26	24				1.79	−2.0	9	8,292	sw.	27	nw.	30	10	7	14	6.0	3.6	1.0
Louisville	525	188	234	29.56	30.16	+.02	34.6	−3.0	59	4	40	15	30	29	27	32	27	76	1.87	−1.9	8	6,694	sw.	32	nw.	29	6	9	16	6.7	2.2	T.
Evansville	431	76	116	29.67	30.16	+.03	35.3	−1.8	61	9	41	16	2	29	29	32	27	74	1.69	−1.8	8	5,823	sw.	22	nw.	29	7	7	17	6.5	4.7	T.
Indianapolis	822	194	230	29.20	30.12	.00	31.1	−1.1	55	9	37	10	2	25	24	29	25	80	0.80	−2.2	8	7,319	sw.	28	nw.	29	9	3	19	6.8	2.9	0.0
Royal Center	736	11	55	29.28	30.11	.....	28.8	.....	50	9	35	7	2	23	25				0.24	−2.4	11	6,945	w.	28	w.	11	8	4	19	6.9	1.8	T.
Terre Haute	575	96	129	29.49	30.13	.....	32.6	.....	57	9	39	12	2	26	26	30	26	80	0.75	−2.2	8	5,947	s.	25	n.	15	8	5	18	6.6	1.8	0.0
Cincinnati	627	11	51	29.43	30.14	+.01	32.6	−0.8	56	11	38	12	2	27	24	30	27	81	1.20	−1.8	8	5,047	sw.	24	nw.	29	5	8	18	6.9	4.0	1.5
Columbus	822	216	230	29.21	30.11	−.01	31.6	−0.8	52	9	37	11	2	26	25	29	25	78	0.80	−1.9	5	7,373	sw.	34	nw.	1	5	3	23	7.7	2.0	0.5
Dayton	899	137	173	29.13	30.12	.....	31.6	−1.0	54	9	37	12	16	26	24	29	26	82	0.97	−1.8	10	6,103	sw.	29	sw.	29	3	6	22	7.9	4.4	0.7
Elkins	1,947	59	67	28.01	30.16	+.04	28.2	−4.5	56	4	37	−7	25	20	41	26	23	84	3.63	+0.2	18	3,604	w.	23	nw.	1	4	6	21	8.1	13.9	4.5
Parkersburg	637	77	82	29.47	30.14	.00	33.4	−1.8	56	10	39	14	2	28	33	30	26	77	2.11	−0.9	11	3,795	sw.	23	nw.	1	3	6	22	8.2	1.6	T.
Pittsburgh	842	353	416	29.17	30.11	.00	31.5	−2.7	50	10	37	8	2	26	26	29	25	77	1.72	−1.1	14	7,243	w.	34	w.	30	3	6	22	8.0	2.8	0.5
Lower Lake Region							**29.3**	**+0.2**										**80**	**1.26**	**−1.5**									**8.4**		
Buffalo	767	247	280	29.17	30.03	−.03	29.3	−0.5	46	11	34	5	2	25	27	27	24	81	1.93	−1.4	19	11,374	w.	60	w.	9	0	5	26	8.9	14.9	2.7
Canton	448	10	61	29.53	30.02	.....	23.9	+1.2	42	12	30	−8	2	17	33				0.83	−1.9	16	5,858	sw.	30	sw.	26	2	5	24	8.4	7.9	1.8
Ithaca	836	74	100	29.11	30.05	.....	28.4	−0.6	44	10	34	6	17	23	24	26	22	79	1.79	−0.6	15	6,356	nw.	28	nw.	12	1	6	24	8.5	17.1	6.4
Oswego	335	71	85	29.66	30.04	−.02	28.4	−0.6	43	7	34	7	2	23	23	27	23	78	1.14	−2.4	18	7,277	s.	29	nw.	1	0	2	29	9.4	8.9	4.1
Rochester	523	86	102	29.47	30.06	.00	29.4	+0.1	49	11	34	5	16	24	23	27	23	76	1.71	−1.0	18	5,507	sw.	30	w.	9	0	2	29	9.4	11.7	1.2
Syracuse	596	65	79	29.38	30.04	−.03	29.2	+0.9	45	12	34	5	16	24	21				1.80	−1.3	16	4,500	s.	19	nw.	12	2	4	25	8.6	8.7	2.2
Erie	714	130	166	29.26	30.06	−.01	30.8	−1.1	47	11	35	9	17	27	25	28	25	79	1.61	−1.2	15	10,098	s.	38	se.	6	0	4	27	8.7	9.8	1.8
Cleveland	762	267	337	29.22	30.07	−.02	32.0	+0.8	53	11	37	10	2	27	23	29	24	74	0.89	−1.6	15	9,996	sw.	50	w.	30	1	6	24	8.6	5.0	1.0
Sandusky	629	5	67	29.38	30.08	−.01	31.0	−0.2	52	11	36	8	2	26	21				0.84	−1.4	16	6,114	sw.	27	nw.	1	3	7	21	8.0	3.5	0.2
Toledo	628	208	243	29.39	30.09	+.01	30.4	0.0	52	11	36	7	16	25	23	27	24	78	0.83	−1.5	15	8,505	sw.	32	w.	9	8	5	18	7.1	4.0	0.2
Fort Wayne	856	100	119	29.14	30.10	.....	29.8	+2.5	52	11	35	8	2	25	22	27	24	83	0.61	−2.0	12	6,549	sw.	27	nw.	1	6	4	21	7.4	2.7	0.5
Detroit	730	218	258	29.26	30.08	+.01	29.6	+0.3	52	9	35	5	2	24	25	28	26	88	1.10	−1.2	13	6,823	sw.	28	sw.	31	6	3	22	7.8	9.1	0.9
Upper Lake Region							**25.7**	**+1.0**										**83**	**1.08**	**−1.1**									**7.8**		
Alpena	609	13	92	29.34	30.03	+.01	25.4	+0.6	44	9	31	−4	2	19	26	24	21	83	0.86	−1.2	14	6,816	sw.	29	nw.	31	3	3	25	8.5	11.3	4.2
Escanaba	612	54	60	29.35	30.04	+.01	24.0	+1.6	50	9	30	−3	1	18	24	22	18	80	0.20	−1.6	7	6,198	nw.	32	n.	29	7	7	17	6.9	4.0	1.5
Grand Haven	632	54	89	29.34	30.05	.00	28.8	−0.5	48	10	34	6	17	23	25	27	25	87	1.69	−0.8	18	7,625	w.	32	w.	31	4	1	26	8.4	24.1	4.0
Grand Rapids	707	70	244	29.29	30.08	+.03	28.6	+0.1	49	10	34	8	2	24	21	26	23	79	1.34	−1.2	14	7,458	sw.	27	s.	2	4	3	24	8.2	18.0	2.0
Houghton	668	64	99	29.28	30.03	+.01	22.9	+1.1	42	8	29	−4	24	17	33				2.19	−0.9	13	6,147	w.	28	w.	28	2	3	26	8.8	22.5	13.5
Lansing	878	6	88	29.08	30.06	.....	26.6	−0.6	48	9	33	−2	2	20	30	25	24	93	0.91	−1.2	13	5,513	sw.	22	nw	29	4	6	21	7.9	7.9	2.8
Ludington	637	60	66	29.33	30.04	.....	28.6	+0.2	46	10	34	8	15	24	20	27	24	81	1.03	−1.4	14	7,252	w.	34	sw.	25	1	7	23	8.5	12.6	2.8
Marquette	734	77	111	29.19	30.02	.00	24.6	+2.0	48	9	30	−3	1	19	24	22	20	83	1.97	−0.7	17	6,932	w.	34	sw.	26	3	2	26	8.5	19.6	13.2
Port Huron	638	70	120	29.33	30.05	−.01	27.7	+0.1	51	9	33	1	16	22	25	25	23	85	2.02	0.0	11	7,096	nw.	27	nw.	30	4	4	23	7.9	23.3	4.5
Sault Sainte Marie	614	11	52	29.30	30.03	+.03	22.0	+1.5	40	9	28	−8	15	16	25	21	20	90	1.32	−1.0	19	5,299	sw.	27	nw.	31	6	4	21	7.3	15.0	10.7
Chicago	673	7	131	29.35	30.10	+.02	29.7	+0.9	51	9	35	7	2	24	27	27	23	76	0.27	−1.8	6	7,066	nw.	28	nw.	29	6	8	17	6.8	3.2	0.0
Green Bay	617	109	141	29.36	30.05	+.01	23.8	+1.5	54	9	30	−2	1	17	26	22	19	82	0.33	−1.4	6	6,598	sw.	26	nw.	29	5	5	21	7.7	3.2	0.8
Milwaukee	681	125	221	29.31	30.07	+.01	27.8	+1.7	54	9	34	−2	2	22	31	25	22	81	0.79	−0.9	10	8,634	w.	33	nw.	31	7	5	19	6.9	9.0	3.3
Duluth	1,133	5	47	28.79	30.07	+.02	19.0	+3.1	50	9	26	−14	1	12	32	17	15	84	0.20	−1.0	6	7,673	nw.	48	nw.	29	5	7	19	7.3	2.0	0.4
North Dakota							**20.9**	**+8.5**										**86**	**0.13**	**−0.4**									**6.2**		
Moorhead	940	50	58	29.03	30.09	+.01	19.8	+8.3	42	10	27	−12	1	12	32	19	17	90	0.10	−0.6	6	5,580	s.	27	nw.	30	6	7	18	7.3	1.2	0.1
Bismarck	1,674	8	57	28.24	30.10	+.02	22.8	+8.1	46	8	30	−1	1	15	27	21	17	78	0.19	−0.4	3	5,552	nw.	36	nw.	10	12	6	13	5.6	2.0	1.9
Devils Lake	1,478	11	44	28.42	30.06	.00	17.0	+7.5	38	8	26	−18	1	8	34	16	15	94	0.23	−0.3	8	5,878	w.	27	nw.	28	8	10	13	6.5	3.0	4.1
Ellendale	1,457	10	56	28.48	30.10	.....	21.6	.....	43	8	30	−6	1	13	29				0.07	−0.4	5	8,881	nw.	35	nw.	10	6	10	15	6.9	1.1	0.2
Grand Forks	833	12	67	.....	.....	.....	16.7	.....	40	8	26	−17	1	8	34	15	.....	.....	0.79	.....	11	.....	nw.	42	nw.	31	7	12	12	.....	8.4	6.5
Williston	1,878	41	48	28.03	30.08	+.02	24.0	+10.2	46	8	31	3	1	17	26	22	19	82	0.05	−0.5	2	4,649	w.	27	w.	10	14	8	9	4.7	0.5	0.5
Upper Mississippi Valley							**28.5**	**+1.7**										**81**	**0.59**	**−1.0**									**6.2**		
Minneapolis	918	102	208	29.05	30.07	.....	23.0	+3.4	45	9	29	−11	1	17	31	.....	.....	.....	0.06	−0.9	2	6,770	nw.	36	nw.	29	7	5	19	7.3	0.7	T.
St. Paul	837	236	261	29.15	30.09	+.01	22.6	+3.6	47	9	29	−11	1	16	32	.....	.....	.....	0.19	−0.9	7	6,829	nw.	35	nw.	29	8	5	18	7.0	3.2	0.3
La Crosse	714	11	48	29.28	30.08	.00	24.5	+2.2	49	9	31	−3	1	18	31	22	20	86	0.26	−1.1	8	3,014	nw.	19	nw.	29	10	2	19	6.6	2.5	T.
Madison	974	70	78	28.99	30.09	+.01	24.4	+1.6	50	9	30	−2	2	18	31	23	21	87	0.68	−1.0	9	5,652	nw.	24	ne.	14	7	6	18	6.7	4.0	1.2
Wausau	1,247	4	62	.....	30.07	.....	20.8	.....	49	9	28	−5	1	14	29	.....	.....	.....	0.28	−1.2	5	3,807	w.	18	nw.	29	9	3	19	.....	3.1	1.5
Charles City	1,015	10	51	29.00	30.12	+.02	23.0	+2.6	48	9	30	0	1	16	29	21	19	86	0.34	−1.0	5	3,895	nw.	20	nw.	29	12	3	16	6.0	2.5	1.3
Davenport	606	71	79	29.44	30.13	+.03	28.0	+0.9	52	10	34	7	31	22	28	26	22	82	0.97	−0.5	6	6,468	w.	40	nw.	29	9	7	15	6.3	4.6	T.
Des Moines	861	5	99	29.19	30.13	+.02	28.6	+2.6	61	9	36	10	16	22	28	26	22	77	0.36	−0.9	4	6,036	nw.	30	nw.	29	9	6	16	6.5	2.0	T.
Dubuque	700	81	96	29.33	30.11	+.01	25.4	+0.7	52	9	32	0	24	19	34	24	22	87	1.24	−0.2	7	3,756	nw.	23	nw.	29	9	6	16	6.2	7.6	1.9
Keokuk	614	64	78	29.45	30.16	+.04	31.6	+2.0	61	9	38	13	30	25	26	28	23	74	0.60	−0.8	4	5,053	sw.	30	nw.	29	9	9	13	5.6	0.7	0.0
Cairo	358	87	93	29.76	30.16	+.01	37.0	−0.8	62	9	43	19	16	31	26	33	29	76	1.97	−1.4	11	5,528	sw.	24	n.	15	8	10	13	5.9	3.5	0.0
Peoria	609	11	45	29.45	30.14	+.03	29.8	+1.7	56	10	37	10	30	23	27	27	24	84	0.29	−1.5	3	4,659	nw.	23	w.	29	8	10	13	5.8	1.2	0.0
Springfield, Ill.	636	5	191	29.42	30.13	+.01	32.2	+0.5	56	9	38	13	30	26	25	29	25	78	0.32	−1.9	3	8,305	nw.	42	nw.	29	10	6	15	6.1	0.6	0.0
Hannibal	534	74	109	29.54	30.14	+.02	33.2	+1.7	62	9	40	15	30	27	24	.....	.....	.....	0.46	−1.1	4	5,777	sw.	24	nw.	29	11	7	13	5.5	0.5	0.0
St. Louis	568	265	303	29.52	30.14	+.01	35.8	+1.1	65	9	43	18	30	29	24	31	26	70	0.90	−1.3	3	8,028	nw.	28	sw.	24	13	5	13	5.3	0.5	0.0
Missouri Valley							**31.5**	**+3.8**										**76**	**0.44**	**−0.6**									**5.2**		
Columbia, Mo	784	6	84	29.28	30.14	+.02	34.2	+1.0	62	9	41	16	17	27	28	.....	.....	.....	0.48	−1.4	4	5,192	sw.	25	nw.	29	13	5	13	5.2	T.	0.0
Kansas City	963	161	181	29.09	30.16	+.04	35.2	+2.7	63	9	42	17	16	28	35	31	26	74	0.95	−0.4	3	6,664	nw.	30	nw.	29	13	9	9	4.6	0.3	0.0
St. Joseph	967	11	49	29.08	30.15	.....	32.6	.....	61	9	40	15	16	26	31	29	25	76	0.70	−0.3	4	4,933	nw.	24	nw.	29	14	7	10	4.8	0.8	0.0
Springfield, Mo	1,324	98	104	28.72	30.16	+.03	35.2	−1.0	60	9	42	14	16	29	23	31	27	77	1.30	−1.0	10	6,229	nw.	24	nw.	29	19	3	9	3.7	4.4	0.0
Iola	984	11	50	29.08	30.17	+.05	35.5	+1.6	63	9	44	16	30	27	33	.....	.....	.....	0.98	−0.4	6	3,834	nw.	17	sw.	24	13	9	9	4.7	0.4	0.0
Topeka	987	92	107	.....	.....	.....	34.1	+2.1	66	9	42	18	16	27	34	.....	.....	.....	0.37	−0.6	2	5,589	w.	27	nw.	29	17	5	9	4.2	0.8	0.0
Lincoln	1,189	11	81	28.85	30.16	+.04	31.8	+4.2	64	9	40	14	21	24	31	28	24	77	0.12	−0.7	4	5,658	w.	28	nw.	29	8	10	13	5.9	1.4	0.0
Omaha	1,105	115	122	28.93	30.16	+.05	31.1	+4.7	60	9	38	13	1	24	27	27	22	72	0.15	−0.8	3	4,979	nw.	29	nw.	29	12	5	14	5.5	1.3	T.
Valentine	2,598	47	54	27.36	30.18	+.08	27.8	+3.2	52	8	37	9	20	19	32	24	21	82	0.18	−0.4	6	5,390	w.	30	sw.	16	13	7	11	5.2	1.4	0.1
Sioux City	1,135	94	164	28.90	30.16	+.04	28.6	+5.5	58	9	36	8	1	22	34	25	21	78	0.30	−0.6	5	6,860	nw.	31	nw.	20	9	9	13	6.1	3.3	T.
Huron	1,306	59	74	28.69	30.14	+.04	26.4	+7.7	53	9	35	6	1	18	38	23	18	76	0.01	−0.6	1	5,701	w.	28	w.	10	12	3	16	5.7	0.1	0.0
Pierre	1,572	70	75	28.42	30.14	+.04	29.0	+7.2	53	8	38	10	1	20	34	25	20	75	0.02	−0.5	2	4,892	nw.	26	nw.	28	11	9	11	5.5	0.1	0.0
Yankton	1,233	49	57	28.79	30.16	+.05	29.4	+6.6	64	9	37	10	30	22	39	.....	.....	.....	0.11	−0.7	2	4,834	nw.	22	nw.	29	12	3	16	5.9	1.1	T.

TABLE 1.—*Climatological data for Weather Bureau stations, December, 1930*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with .01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, andince on ground at end of month
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	*In.*	*In.*		*Miles*								*0–10*	*In.*	*In.*
Northern Slope							**27.2**	**+3.3**										**73**	**0.18**	**−0.6**										**4.7**		
Billings	3,140	5					34.0		60	9	47	8	31	21	38				T.		0		nw.				21	5	5		T.	
Havre	2,505	11	44	27.41	30.12	+0.07	29.2	+8.8	50	8	38	7	21	20	30	26	22	76	0.26	−0.4	4	7,506	sw.	26	sw.	9	15	11	5	4.3	2.1	0.3
Helena	4,124	89	113	25.91	30.25	+.12	29.4	+5.2	49	9	36	8	26	22	30	24	17	62	T.	−0.8	0	5,393	sw.	28	sw.	23	8	13	10	5.5	T.	0.0
Kalispell	2,973	48	56	27.14	30.32	+.25	24.4	−0.5	41	14	30	3	30	19	18	24	22	89	0.35	−1.1	7	1,981	nw.	17	w.	16	1	7	23	8.4	5.2	5.7
Miles City	2,371	48	55	27.55	30.18	+.08	30.4	+9.4	58	8	40	12	31	20	31	26	22	76	0.31	−0.3	7	3,287	s.	18	nw.	10	15	9	7	4.5	1.4	T.
Rapid City	3,259	50	58	26.66	30.19	+.10	32.8	+5.9	64	8	43	10	16	23	32	27	21	68	0.21	−0.2	2	4,722	w.	24	n.	28	11	10	10	4.9	2.5	0.0
Cheyenne	6,088	84	101	24.03	30.21	+.12	28.9	+0.4	61	8	40	8	19	18	38	21	12	54	0.12	−0.4	4	8,059	w.	32	w.	23	18	6	7	3.5	1.2	T.
Lander	5,372	60	68	24.72	30.31	+.16	21.6	+1.2	51	10	34	−4	27	9	36	17	13	79	0.10	−0.6	3	1,551	sw.	11	se.	18	21	6	4	3.1	1.4	T.
Sheridan	3,790	10	47	26.16	30.20		29.0		61	8	44	6	25	14	41	23	17	68	0.03	−0.6	2	2,488	nw.	20	nw.	30	15	12	4	4.1	0.3	0.0
Yellowstone Park	6,241	11	48	23.99	30.42	+.26	18.6	−3.0	39	9	28	−3	27	10	25	15	10	74	0.27	−1.2	3	3,866	sw.	25	w.	9	10	10	11	5.3	7.1	11.0
North Platte	2,821	11	51	27.15	30.19	+.09	29.4	+2.7	48	8	38	14	19	21	28	25	22	82	0.17	−0.4	3	4,081	w.	23	n.	12	20	3	8	3.7	1.6	T.
Middle Slope							**33.9**	**+0.4**										**71**	**1.22**	**+0.3**										**3.9**		
Denver	5,292	106	113	24.78	30.21	+.13	32.2	−0.1	61	8	44	9	19	21	40	25	16	56	0.62	−0.1	4	4,611	s.	20	w.	12	14	13	4	3.6	10.6	0.1
Pueblo	4,685	80	86	25.33	30.18	+.10	29.7	−1.8	62	9	46	3	20	14	49	22	14	59	0.13	−0.4	2	2,955	nw.	18	nw.	12	18	11	2	3.1	1.7	0.0
Concordia	1,392	50	58	28.67	30.20	+.09	32.4	+1.7	57	10	40	14	21	25	32	28	25	78	0.10	−0.5	5	4,408	w.	21	nw.	29	16	4	11	4.4	1.1	0.0
Dodge City	2,509	11	51	27.53	30.23	+.13	33.2	+0.6	59	8	43	11	20	23	32	28	25	81	0.57	0.0	5	5,169	nw.	19	se.	17	19	4	8	3.3	5.0	T.
Wichita	1,358	139	158	28.69	30.17	+.06	35.6	+1.0	58	2	43	19	21	28	33	32	28	78	0.58	−0.4	5	6,338	n.	30	s.	24	16	6	9	3.9	4.4	0.0
Broken Arrow	765	11	56	29.33	30.18		39.4		63	9	48	22	30	31	30				3.01	+1.5	8	7,493	nw.	30	n.	5	15	6	10	4.5	2.4	0.0
Oklahoma City	1,214	10	47	28.86	30.18	+.07	40.4	+1.1	62	9	49	24	21	32	28	35	30	75	3.52	+2.0	7	5,477	s.	22	nw.	5	17	3	11	4.4	2.1	0.0
Southern Slope							**42.0**	**−2.0**										**67**	**0.96**	**+0.1**										**3.9**		
Abilene	1,738	10	52	28.34	30.20	+.09	42.9	−3.1	67	10	53	16	22	33	30	37	32	74	2.43	+1.1	4	5,064	s.	27	s.	17	14	4	13	5.0	6.0	0.0
Amarillo	3,676	10	49	26.35	30.18	+.09	37.6	+0.6	61	8	48	17	28	27	32	29	23	64	0.46	−0.3	4	4,865	nw.	21	nw.	14	20	4	7	3.2	4.2	T.
Del Rio	944	64	71	29.14	30.15	+.05	49.5	−2.7	71	14	59	27	23	40	32	43	36	66	0.70	0.0	3	4,685	se.	28	nw.	21	10	11	10	5.0	0.0	0.0
Roswell	3,566	75	85	26.47	30.18	+.11	38.2	−3.0	62	10	51	18	26	26	35	31	24	64	0.26	−0.4	3	3,856	n.	33	nw.	14	22	6	3	2.5	0.5	0.0
Southern Plateau							**40.6**	**−1.2**										**50**	**0.10**	**−0.6**										**2.1**		
El Paso	3,778	152	175	26.28	30.15	+.12	43.0	−1.9	63	3	53	21	23	33	31	35	24	54	0.43	−0.1	5	5,413	nw.	29	ne.	14	23	4	4	2.5	T.	0.0
Sante Fe	7,013	38	53	23.26	30.22	+.16	27.8	−2.9	50	12	39	5	22	16	32	20	11	55	0.06	−0.7	1	3,664	ne.	22	n.	22	20	8	3	2.6	1.5	T.
Flagstaff	6,907	10	59	23.38	30.14	+.08	28.3	−0.1	56	11	44	2	21	13	45	22		69	0.11		2	4,566	e.	31	nw.	14	17	13	1		T.	T.
Phoenix	1,108	10	107	28.90	30.07	+.03	52.2	+0.2	74	1	67	28	20	38	37	41	27	43	T.	−1.0	0	3,024	e.	21	e.	23	23	5	3	2.1	0.0	0.0
Yuma	141	9	54	29.95	30.10	+.05	53.8	−1.4	75	9	67	30	27	41	35	41	22	30	0.00	−0.5	0	4,300	n.	24	n.	21	27	3	1	1.1	0.0	0.0
Independence	3,957	6	27	26.10	30.23	+.11	38.2	−1.1	68	13	55	10	22	22	41	26			0.00	−0.8	0		nw.				23	6	2		0.0	0.0
Middle Plateau							**25.3**	**−5.0**										**69**	**0.14**	**−0.8**										**3.5**		
Reno	4,532	74	81	25.62	30.31	+.16	31.4	−2.3	60	12	45	9	25	18	35	26	18	61	0.00	−1.0	0	2,086	w.	25	w.	13	19	8	4	3.0	T.	0.0
Tonopah	6,090	12	20				32.2		52	10	40	12	20	25	20	25	14	47	T.		0		nw.									
Winnemucca	4,344	18	56	25.81	30.36	+.18	25.8	−4.2	55	11	40	−4	20	11	39	21	17	76	0.06	−1.0	1	4,172	ne.	22	nw.	16	17	11	3	2.8	0.7	0.0
Modena	5,473	10	43	24.75	30.32	+.20	20.6	−7.5	50	13	32	−4	22	9	44	17	14	81	T.	−0.8	0	4,066	e.	24	nw.	13	18	8	5	3.4	T.	0.0
Salt Lake City	4,360	163	203	25.85	30.40	+.25	22.5	−9.4	36	4	28	6	31	17	21	21	19	84	0.54	−0.9	5	2,675	nw.	18	w.	17	13	7	11	4.9	8.5	5.3
Grand Junction	4,602	60	68	25.55	30.27	+.17	26.1	−1.4	48	9	38	6	30	14	31	21	14	66	0.11	−0.5	3	3,219	se.	18	se.	31	16	8	7	3.4	1.2	0.0
Northern Plateau							**25.8**	**−5.6**										**85**	**0.79**	**−0.9**										**6.6**		
Baker	3,471	48	53	26.69	30.43	+.27	21.0	−6.3	40	13	30	−2	30	12	26	19	16	82	0.64	−1.1	10	3,472	se.	16	se.	22	10	8	13	5.5	6.7	1.5
Boise	2,739	79	87	27.48	30.48	+.28	23.9	−8.2	41	11	32	4	30	16	25	22	19	82	0.54	−1.0	5	1,948	se.	14	se.	7	7	14	10	5.7	4.6	1.2
Lewiston	757	40	48	29.52	30.37	+.24	32.1	−3.6	48	5	38	15	30	26	18				0.76	−0.7	8	2,558	e.	15	w.	16	6	9	16	6.6	2.2	0.0
Pocatello	4,477	60	68	25.69	30.46	+.24	17.2	−10.5	37	13	26	−8	27	9	26	16	13	84	1.22	0.0	5	4,380	se.	26	sw.	13	13	7	11	5.3	16.5	12.0
Spokane	1,929	101	110	28.22	30.36	+.28	28.2	−2.3	38	5	32	12	25	24	15	28	26	90	0.86	−1.3	10	2,302	n.	14	s.	17	0	8	23	8.5	8.6	2.0
Walla Walla	991	57	65	29.24	30.35	+.23	32.7	−2.8	52	11	37	20	31	29	21	31	29	89	0.74	−1.3	11	2,019	s.	15	w.	18	1	10	20	8.2	0.5	0.0
North Pacific Coast Region							**41.3**	**+0.7**										**83**	**2.45**	**−3.8**										**7.9**		
North Head	211	11	56	29.95	30.18	+.15	45.6	+1.5	54	1	49	34	26	42	14	42	39	79	4.90	−4.6	20	10,248	se.	58	s.	8	4	8	19	7.2	0.0	0.0
Port Angeles	29	8	53		30.16		41.8		56	2	46	30	29	37	17				0.99	−3.8	14	3,603	s.	23	sw.	16	2	9	20		0.0	0.0
Seattle	125	215	250	30.06	30.19	+.18	43.1	+1.4	55	11	48	27	28	38	14	40	36	77	1.85	−3.8	14	4,608	se.	33	s.	9	3	14	14	6.7	0.0	0.0
Tacoma	194	172	201	29.98	30.19	+.18	40.8	+0.2	56	11	46	25	27	35	21				1.97	−4.7	16	3,659	s.	27	s.	22	0	7	24	8.5	0.0	0.0
Tatoosh Island	86	9	53	30.04	30.13	+.17	46.4	+2.5	56	8	49	39	28	44	11	44	42	88	5.84	−7.5	20	12,718	e.	50	e.	12	3	4	24	8.4	0.0	0.0
Yakima	1,076	58	67	29.17	30.36		31.6	+0.9	48	17	36	19	31	28	21	29	27	83	0.26	−1.1	7	1,829	se.	21	nw.	17	2	3	26	8.9	0.9	T.
Medford	1,329	29	58	28.80	3n. 26		36.2		60	12	44	16	28	28	26	35	33	88	1.06	−2.0	12		nw.	32	se.	12	2	7	22	8.1	0.2	0.0
Portland, Oreg	153	68	106	30.08	30.24	+.17	40.4	−0.8	55	9	45	28	31	36	19	38	34	78	3.16	−3.6	16	4,071	e.	20	e.	30	3	6	22	8.0	T.	0.0
Roseburg	510	75	99	29.67	30.24	+.13	41.0	−0.8	62	12	48	26	22	34	22	39	37	88	2.02	−3.3	14	1,752	e.	19	s.	31	0	14	17	7.5	0.0	0.0
Middle Pacific Coast Region							**48.3**	**−0.1**										**71**	**1.21**	**−2.9**										**4.1**		
Eureka	62	73	89	30.15	30.22	+.10	48.0	−0.2	64	12	56	34	24	40	26	46	44	86	2.50	−3.8	10	3,071	se.	31	se.	31	13	6	12	5.0	0.0	0.0
Red Bluff	330	5	58	29.84	30.20	+.06	47.2	+1.1	68	7	59	20	24	35	35	39	29	55	1.51	−2.9	6	3,590	nw.	25	s.	31	16	8	7	4.2	0.0	0.0
Sacramento	69	106	117	30.12	30.19	+.05	46.0	−0.2	64	2	57	26	28	35	28	43	39	75	0.56	−2.5	3	3,573	nw.	28	nw.	16	21	6	4	3.0	0.0	0.0
San Francisco	155	208	243	30.00	30.17	+.05	52.1	+0.8	63	16	58	39	24	46	15	46	40	68	0.98	−3.0	3	3,686	n.	32	sw.	31	13	11	7	4.5	0.0	0.0
San Jose	141	12	110	30.03	30.19		48.0	−1.9	69	10	60	24	24	36	34				0.49	−2.1	3	3,304	nw.	29	se.	31	17	7	7	3.7	0.0	0.0
South Pacific Coast Region							**54.6**	**+1.7**										**56**	**0.00**	**−2.0**										**2.9**		
Fresno	327	89	98	29.83	30.20	+.07	46.6	+0.4	66	15	58	26	26	35	29	40	34	68	0.01	−1.4	1	2,316	nw.	13	se.	31	15	8	8	4.2	0.0	0.0
Los Angeles	338	159	191	29.74	30.10	+.03	60.1	+3.5	81	8	71	40	22	50	30	47	33	42	0.00	−2.6	0	3,258	ne.	13	ne.	26	25	5	1	2.0	0.0	0.0
San Diego	87	62	70	29.98	30.08	+.01	57.1	+1.1	76	14	67	41	22	47	27	48	40	58	0.00	−1.9	0	2,617	nw.	15	s.	26	22	5	4	2.5	0.0	0.0
West Indies																																
San Juan, P. R.	82	9	54	29.88	29.96		77.2	+0.9	84	6	82	71	6	72	13				5.36	−0.1	21	6,695	e.	39	e.	26	13	17	1	4.3	0.0	0.0
Panama Canal																																
Balboa Heights	118	7	97		29.81		81.0		92	5	89	70	31	74	19			81	2.49		8	5,582	n.	25	n.	23	12	14	5	4.9	0.0	0.0
Cristobal	36	7	97		29.83		82.4		88	3	86	75	1	78	12	76	74	78	7.86		17	10,024	n.	33	nw.	9	7	20	4	5.1	0.0	0.0
Alaska																																
Fairbanks	455	11	44	[1]28.98	[1]29.54		0.1		31	5	8	−21	15	−8	34	0	−3	84	0.21		4	891	n.	9	ne.	4	5	7	19	6.9	5.0	11.5
Juneau	80	11	50	[1]29.55	[1]29.67		39.0		50	6	42	30	9	36	13	38	36	89	12.86		29	6,637	se.	34	e.	26	0	1	30	9.8	0.6	0.0
Hawaiian Islands																																
Honolulu	38	86	100	[1]30.04	[1]30.08		74.1	+1.7	82	14	78	66	28	70	13	68	65	76	0.89	−3.1	15	6,176	e.	30	e.	22	10	15	6	4.9	0.0	0.0
LATE REPORT																																
Yellowstone Park (January)	6,241	11	48	23.78	30.26	+.12	4.8	−12.8	37	31	14	−34	17	−5	36	2	−1	79	0.88	−0.7	12	4,213	sw.	30	s.	3	8	12	11	5.9	16.4	3.4

[1] Observations taken bi-hourly.

[2] Pressure not reduced to mean of 24 hours.

TABLE 2.—*Data furnished by the Canadian Meteorological Service, December, 1930*

Stations	Altitude above mean sea level, Jan. 1, 1919	Pressure			Temperature of the air						Precipitation		
		Station reduced to mean of 24 hours	Sea level reduced to mean of 24 hours	Departure from normal	Mean max. + mean min. ÷2	Departure from normal	Mean maximum	Mean minimum	Highest	Lowest	Total	Departure from normal	Total snowfall
	Feet	*Inches*	*Inches*	*Inches*	*°F.*	*°F.*	*°F.*	*°F.*	*°F.*	*°F.*	*Inches*	*Inches*	*Inches*
Cape Race, N. F.	99				32.5		39.6	25.5	52	10	9.19		7.0
Sydney, C. B. I.	48	29.85	29.90	+0.01	30.4	+2.2	35.5	25.4	55	14	7.44	+2.81	37.7
Halifax, N. S.	88	29.82	29.93	−.03	28.1	+0.5	34.7	21.5	53	6	7.13	+2.01	21.3
Yarmouth, N. S.	65	29.80	29.87	−.11	31.0	+0.3	36.6	25.4	53	9	6.19	+1.42	23.2
Charlottetown, P. E. I.	38	29.82	29.86	−.08	26.5	+2.2	32.0	21.0	50	6	4.67	+1.01	29.2
Chatham, N. B.	28	29.84	29.88	−.06	17.9	+0.9	26.6	9.3	37	−11	1.84	−1.38	11.2
Father Point, Que.	20												
Quebec, Que.	296	29.68	30.02	+.01	19.6	+4.4	25.0	14.3	36	−10	3.40	−0.29	33.1
Doucet, Que.	1,236												
Montreal, Que.	187												
Ottawa, Ont.	236												
Kingston, Ont.	285	29.72	30.04	.00	26.9	+3.2	32.7	21.1	42	−6	1.51	−1.73	2.6
Toronto, Ont.	379	29.62	30.05	.00	28.7	+1.7	33.7	23.8	45	1	1.16	−1.75	6.4
Cochrane, Ont.	930				13.0		19.0	7.0	39	−23	1.98		17.6
White River, Ont.	1,244	28.60	29.97	.00	13.3	+3.6	21.4	5.2	36	−29	1.36	−0.35	13.6
London, Ont.	808												
Southampton, Ont.	656												
Parry Sound, Ont.	688	29.28	30.01	.00	23.5	+2.3	29.3	17.8	40	−13	4.46	−0.02	38.5
Port Arthur, Ont.	644	29.29	30.02	+.03	18.6	+5.4	25.5	11.7	40	−12	0.62	−0.25	6.2
Winnipeg, Man.	760	29.17	30.05	+.03	13.3	+9.2	19.7	7.0	38	−20	0.59	−0.32	5.9
Minnedosa, Man.	1,690	28.13	30.03	+.01	15.8	+10.1	24.9	6.8	38	−24	0.22	−0.40	2.2
Le Pas, Man.	860				13.5		23.9	3.2	38	−22	0.53		5.3
Qu'Appelle, Sask.	2,115	27.66	29.99	−.01	19.6	+12.2	27.7	11.6	45	−17	0.34	−0.18	3.4
Moose Jaw, Sask.	1,759				25.7		35.0	16.3	52	−7	0.15		0.7
Swift Current, Sask.	2,392	27.38	29.98	−.01	26.2	+10.2	36.3	16.2	56	−2	0.25	−0.53	2.5
Medicine Hat, Alb.	2,144												
Calgary, Alb.	3,428												
Banff, Alb.	4,521												
Prince Albert, Sask.	1,450	28.36	29.99	−.02	19.8	+17.0	28.7	10.9	40	−17	0.15	−0.59	1.3
Battleford, Sask.	1,592	28.26	30.08	+.09	19.9	+14.5	28.9	10.9	40	−7	0.15	−0.17	1.5
Edmonton, Alb.	2,150												
Kamloops, B. C.	1,262												
Victoria, B. C.	230	29.91	30.17	+.20	43.1	+1.9	46.7	39.6	52	33	0.78	−7.20	0.0
Barkerville, B. C.	4,180												
Estevan Point, B. C.	20												
Prince Rupert, B. C.	170												
Hamilton, Ber.	151												

LATE REPORTS, NOVEMBER, 1930

Cape Race, N. F.	99				39.8		46.6	32.9	55	13	5.92		6.0
Father Point, Que.	20	30.00	30.02	+.06	33.6	+4.7	39.5	27.7	55	10	2.34	−0.77	3.8
Doucet, Que.	1,236				29.0		36.3	23.5	50	−15	0.64		5.6
Cochrane, Ont.	930				29.9		36.3	23.5	55	−9	1.70		9.1
Calgary, Alb.	3,428	26.42	30.08	+.10	30.8	+5.0	41.9	19.7	62	−12	1.27	+0.39	12.7
Kamloops, B. C.	1,262	28.85	30.18	+.22	36.6	+3.2	40.5	32.8	62	20	0.83	−0.63	5.0
Estevan Point, B. C.	20				44.1		49.8	38.4	58	27	8.18		0.0
Prince Rupert, B. C.	170				42.2		46.2	38.2	54	28	7.31		T.

Chart I. Departure (°F.) of the Mean Temperature from the Normal, December, 1930

Chart I. Departure (°F.) of the Mean Temperature from the Normal, December, 1930

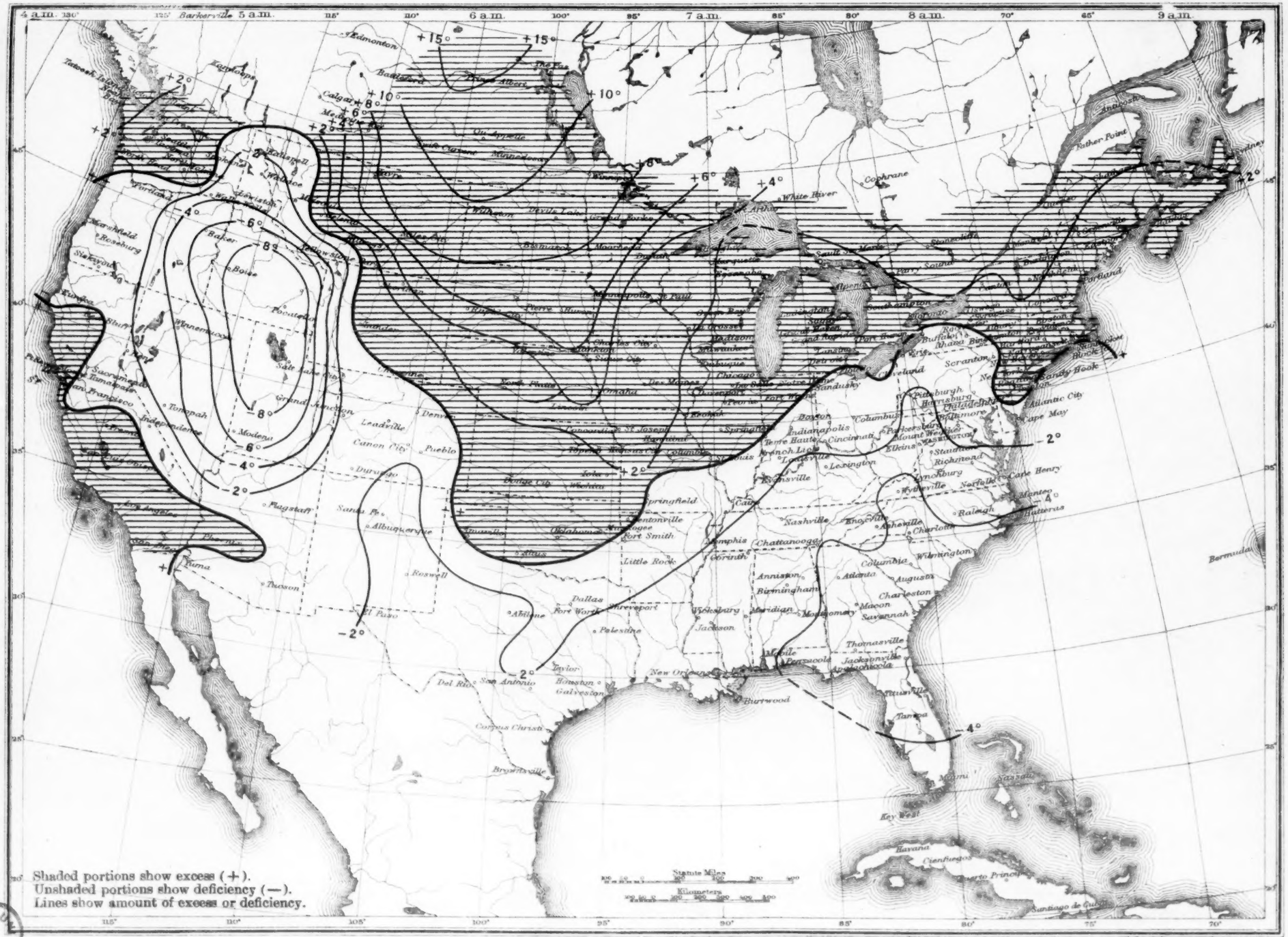
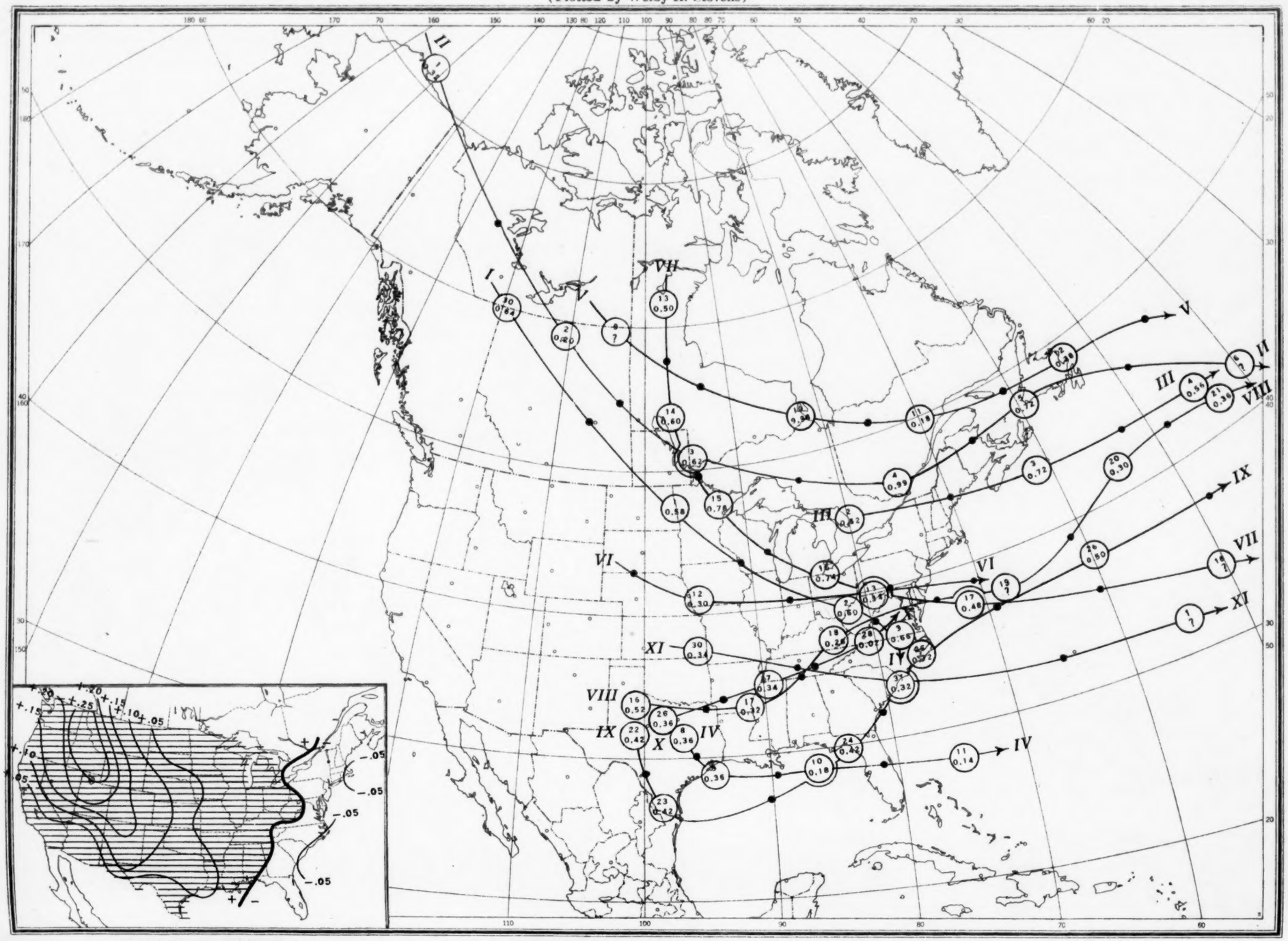


Chart II. Tracks of Centers of Anticyclones, December, 1930. (Inset) Departure of Monthly Mean Pressure from Normal

(Plotted by Welby R. Stevens)



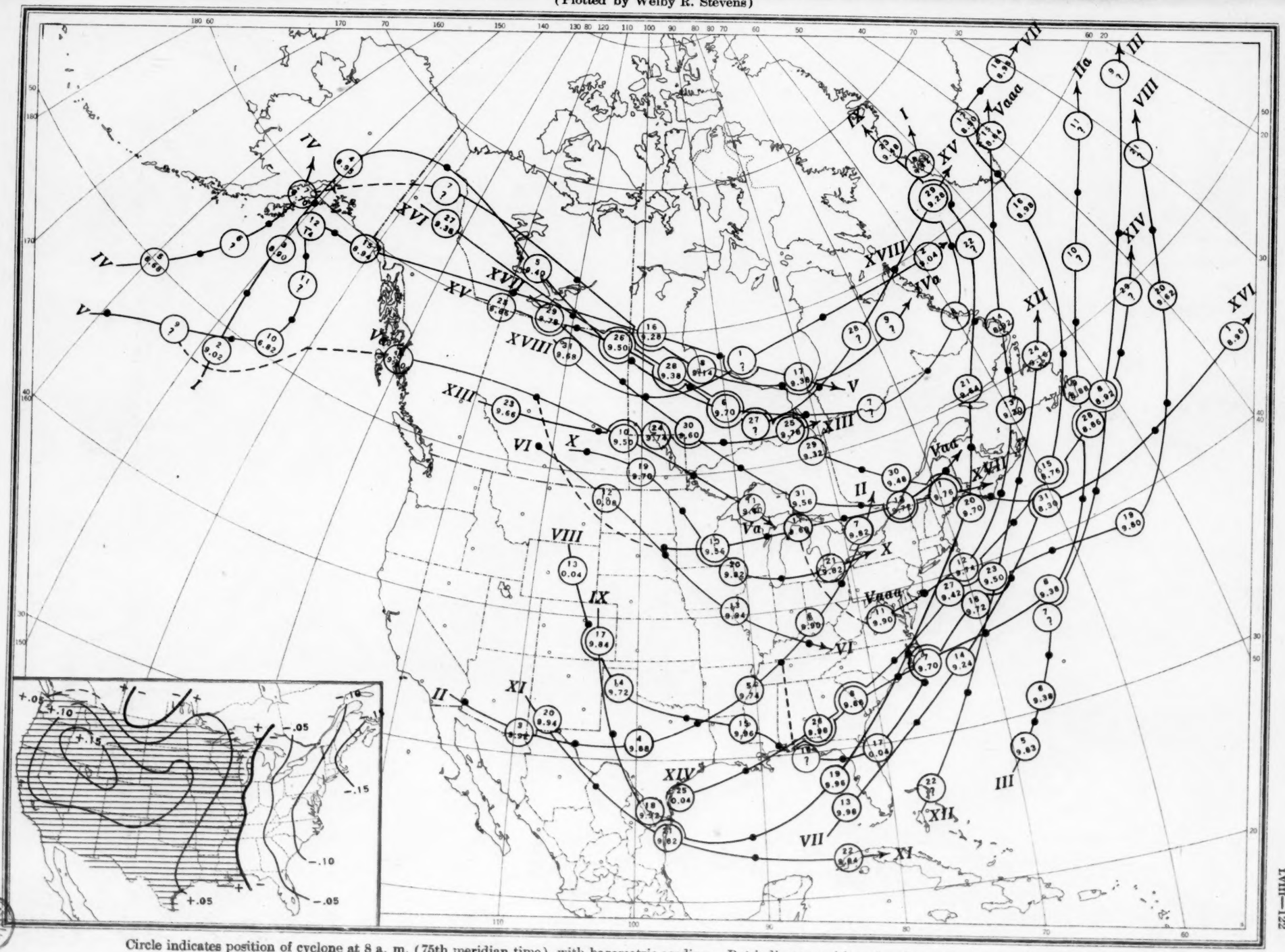
Circle indicates position of anticyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of anticyclone at 8 p. m. (75th meridian time).

Chart III. Tracks of Centers of Cyclones, December, 1930. (Inset) Change in Mean Pressure from Preceding Month

(Plotted by Welby R. Stevens)

Circle indicates position of anticyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of anticyclone at 8 p. m. (75th meridian time).

Chart III. Tracks of Centers of Cyclones, December, 1930. (Inset) Change in Mean Pressure from Preceding Month
(Plotted by Welby R. Stevens)



UNIV. OF MICH.

Circle indicates position of cyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of cyclone at 8 p. m. (75th meridian time).

Chart IV. Percentage of Clear Sky between Sunrise and Sunset, December, 1930

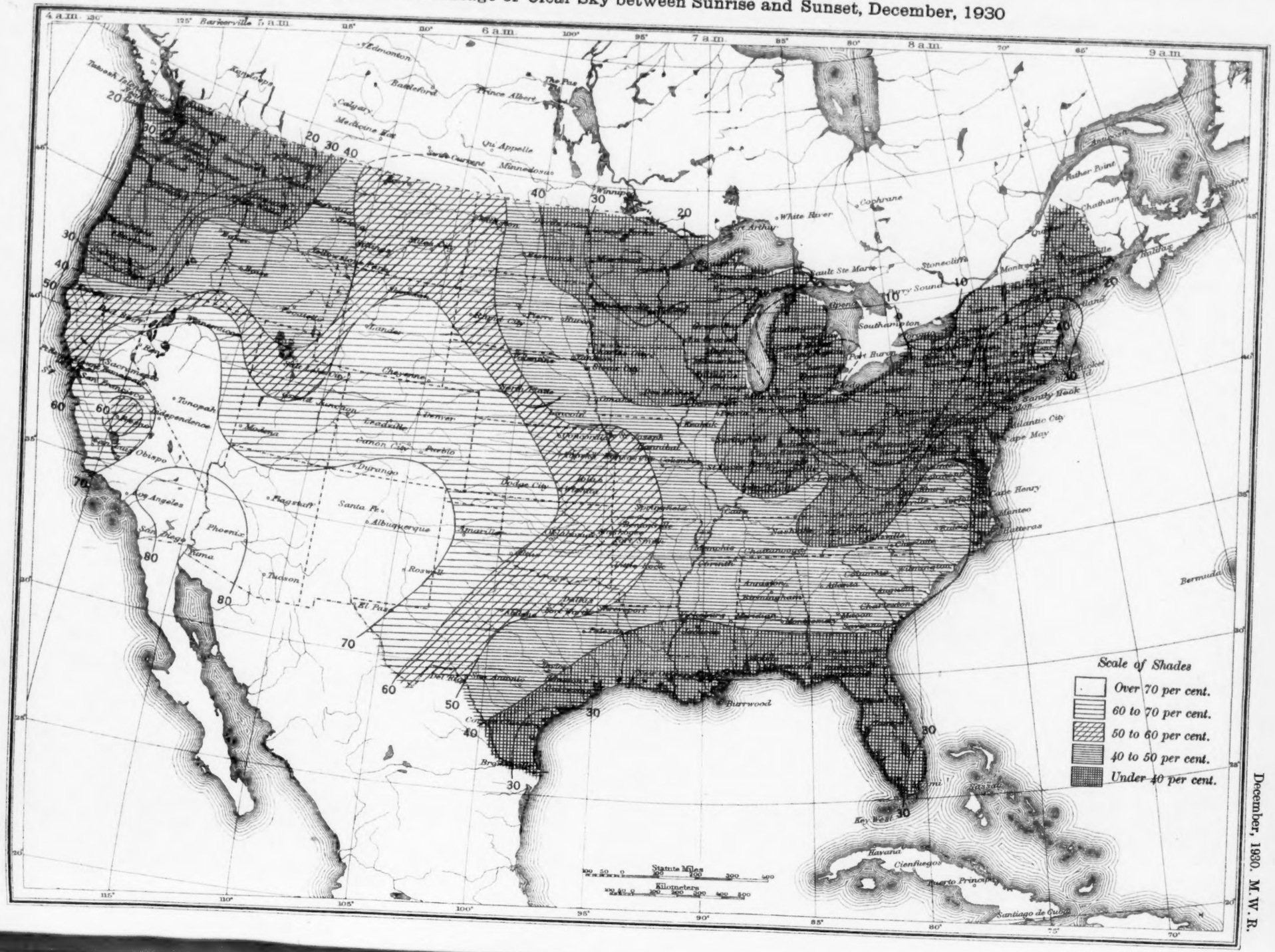
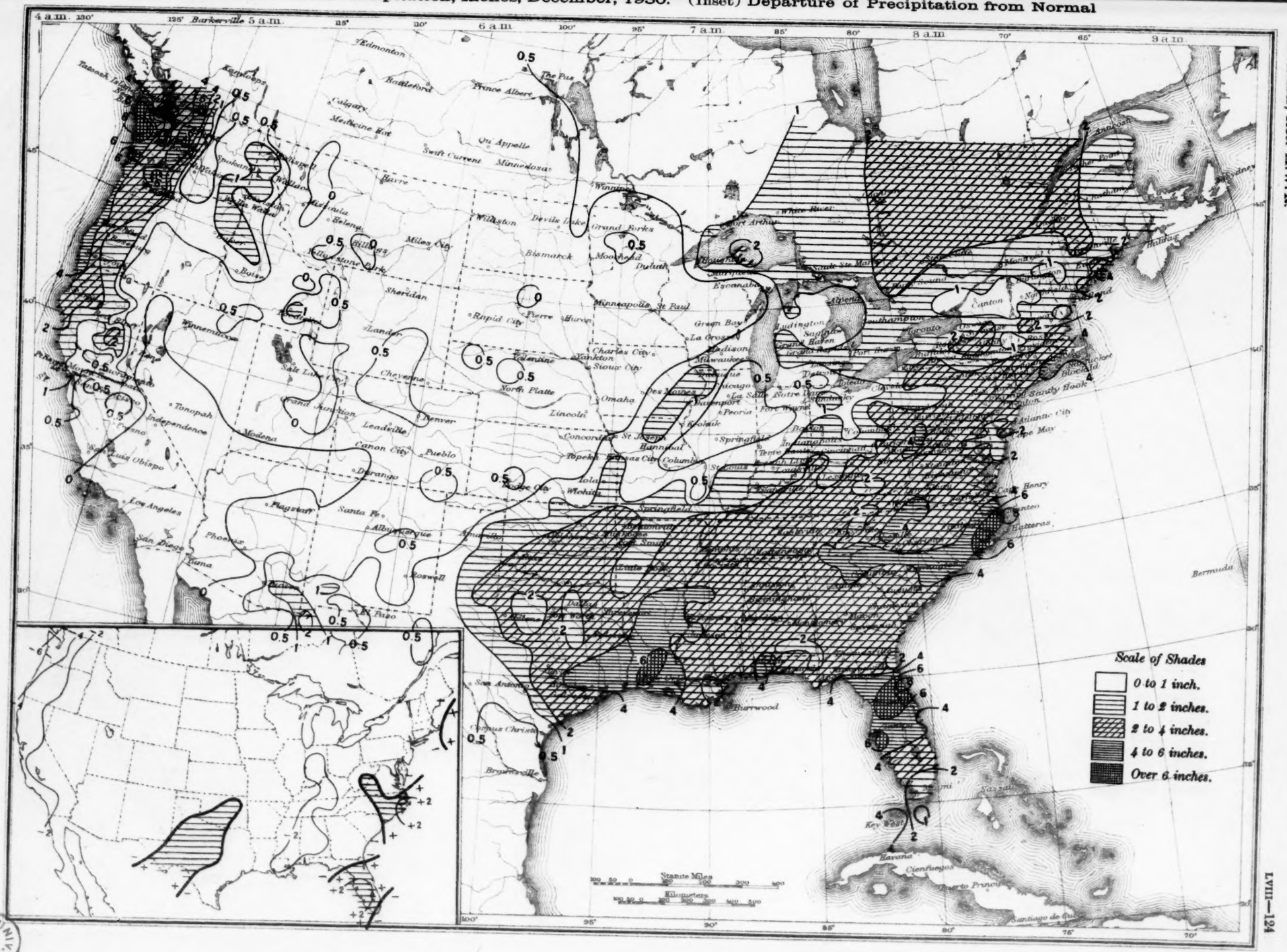


Chart V. Total Precipitation, Inches, December, 1930. (Inset) Departure of Precipitation, Inches, from the Normal

Chart V. Total Precipitation, Inches, December, 1930. (Inset) Departure of Precipitation from Normal



UNIV. OF MICH.

Chart VI. Isobars at Sea level and Isotherms at Surface; Prevailing Winds, December, 1930

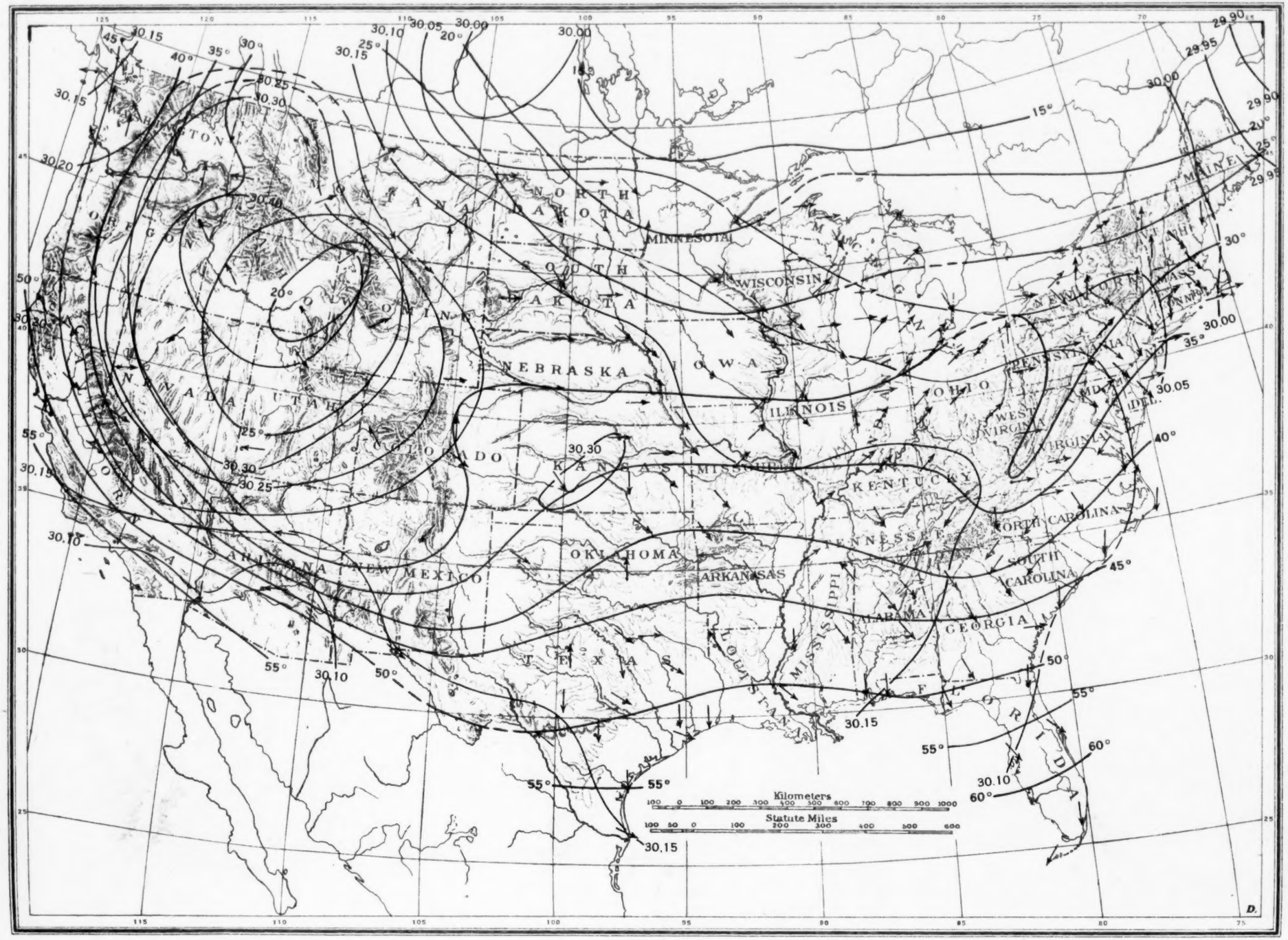


Chart VII. Total Snowfall, Inches, December, 1930. (Inset) Depth of Snow on Ground at end of Month

Chart VII. Total Snowfall, Inches, December, 1930. (Inset) Depth of Snow on Ground at end of Month

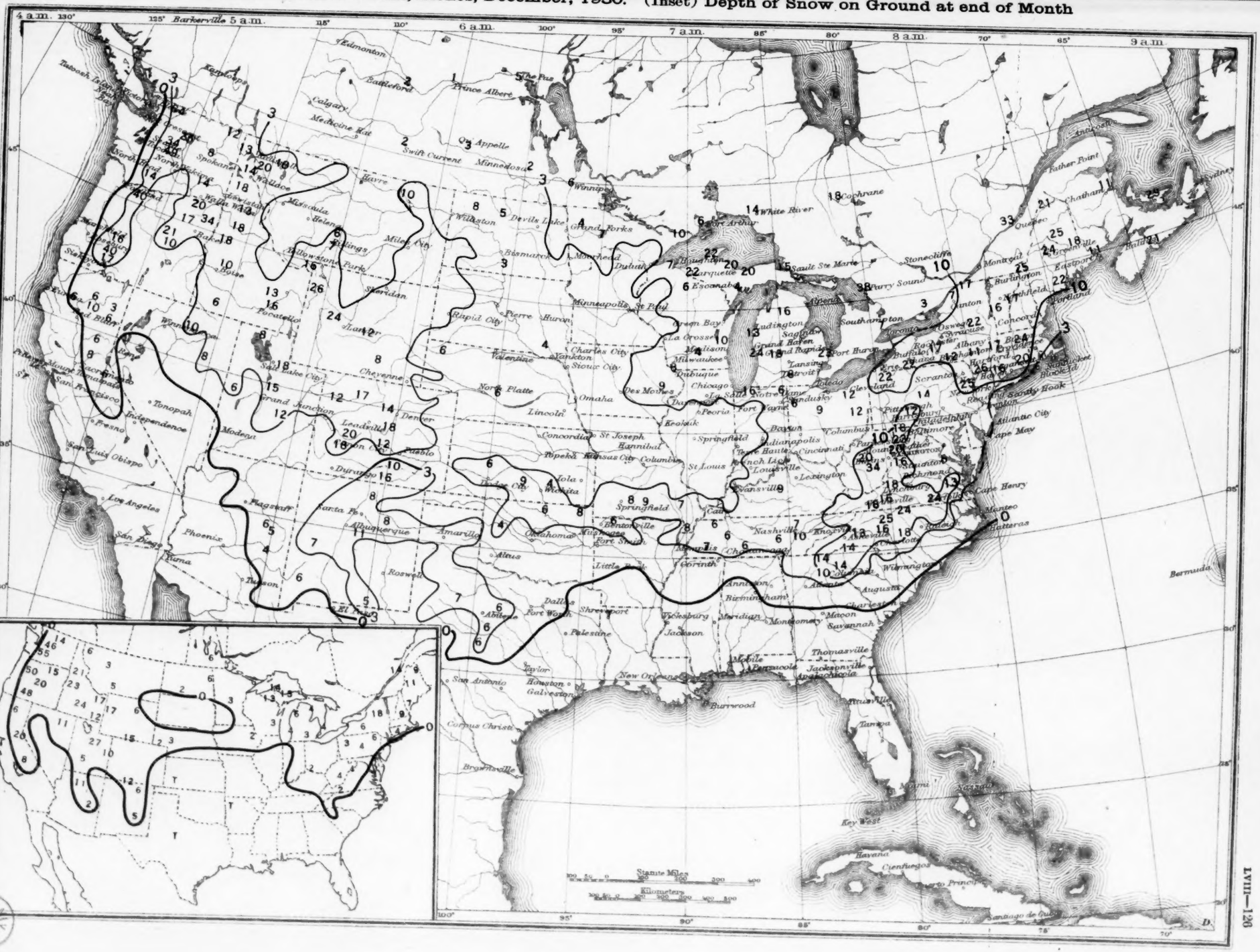
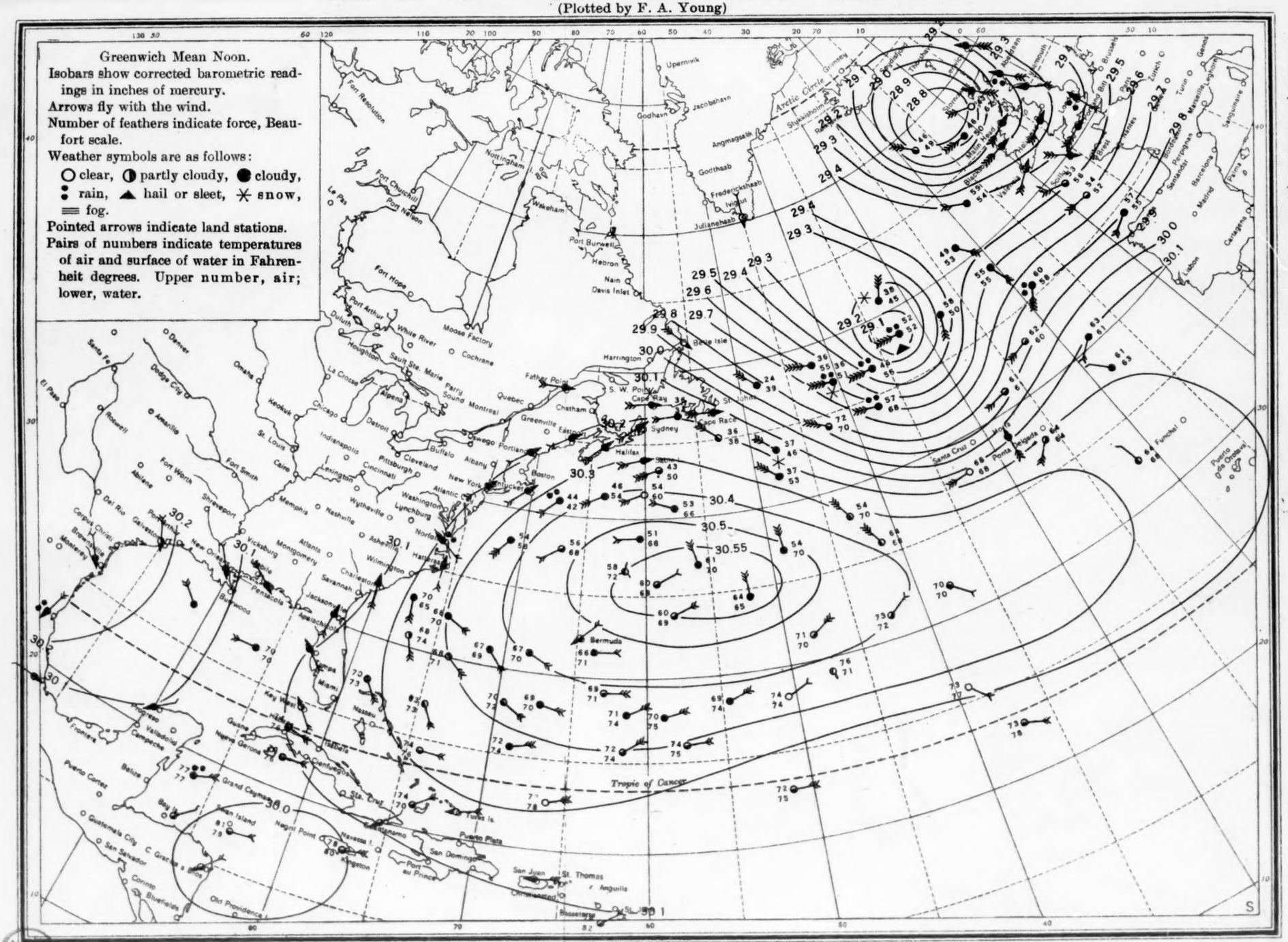


Chart VIII. Weather Map of North Atlantic Ocean, December 26, 1930

(Plotted by F. A. Young)

Chart VIII. Weather Map of North Atlantic Ocean, December 26, 1930

(Plotted by F. A. Young)



UNIV. OF MICH.

Chart IX. Weather Map of North Atlantic Ocean, December 27, 1930

(Plotted by F. A. Young)

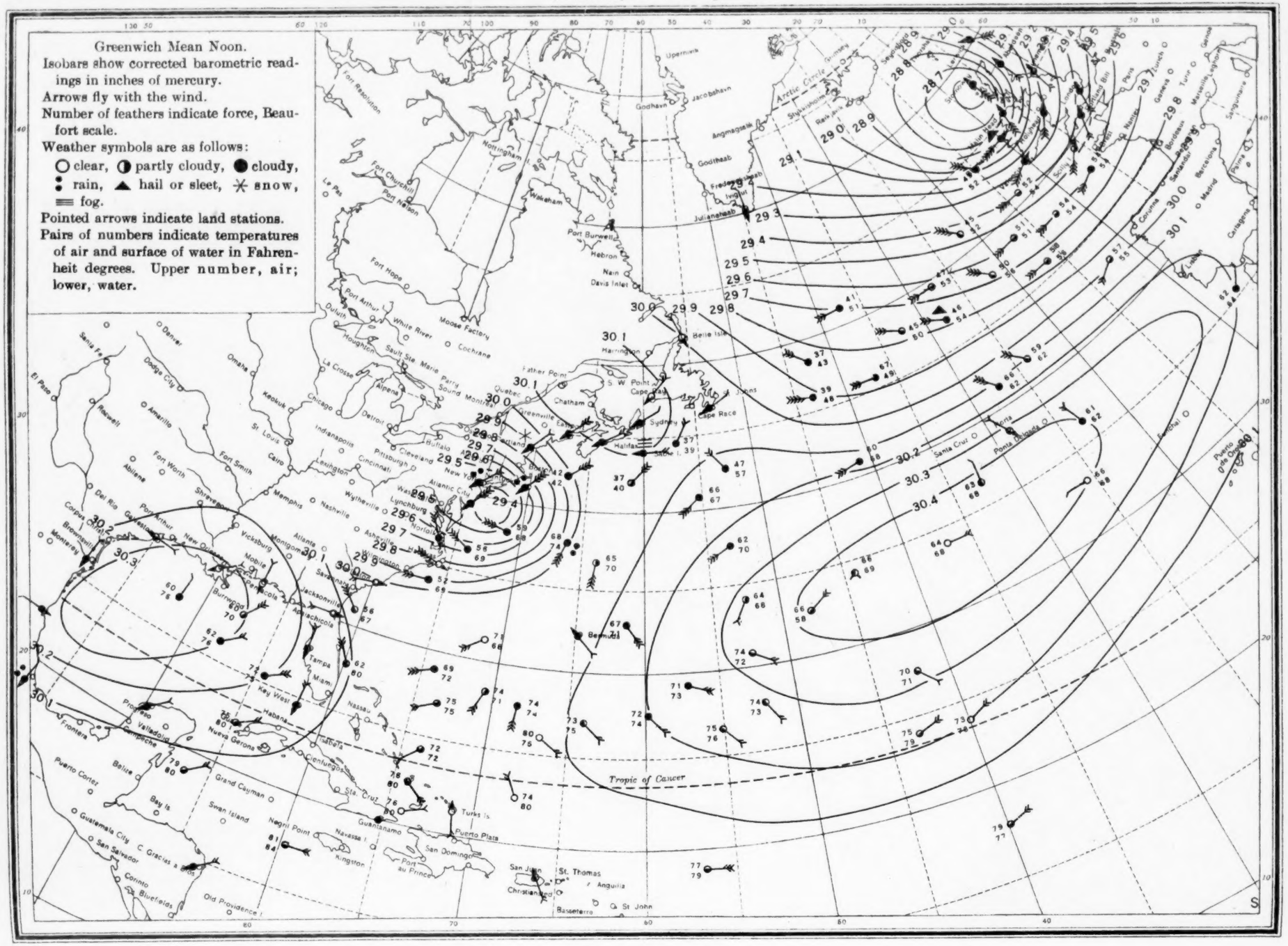

Greenwich Mean Noon.
Isobars show corrected barometric readings in inches of mercury.
Arrows fly with the wind.
Number of feathers indicate force, Beaufort scale.
Weather symbols are as follows:
○ clear, ◑ partly cloudy, ● cloudy,
⁝ rain, ▲ hail or sleet, ✳ snow,
≡ fog.
Pointed arrows indicate land stations.
Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water.
Arctic Circle
Tropic of Cancer

Chart X. Weather Map of North Atlantic Ocean, December 28, 1930

Chart X. Weather Map of North Atlantic Ocean, December 28, 1930

(Plotted by F. A. Young)

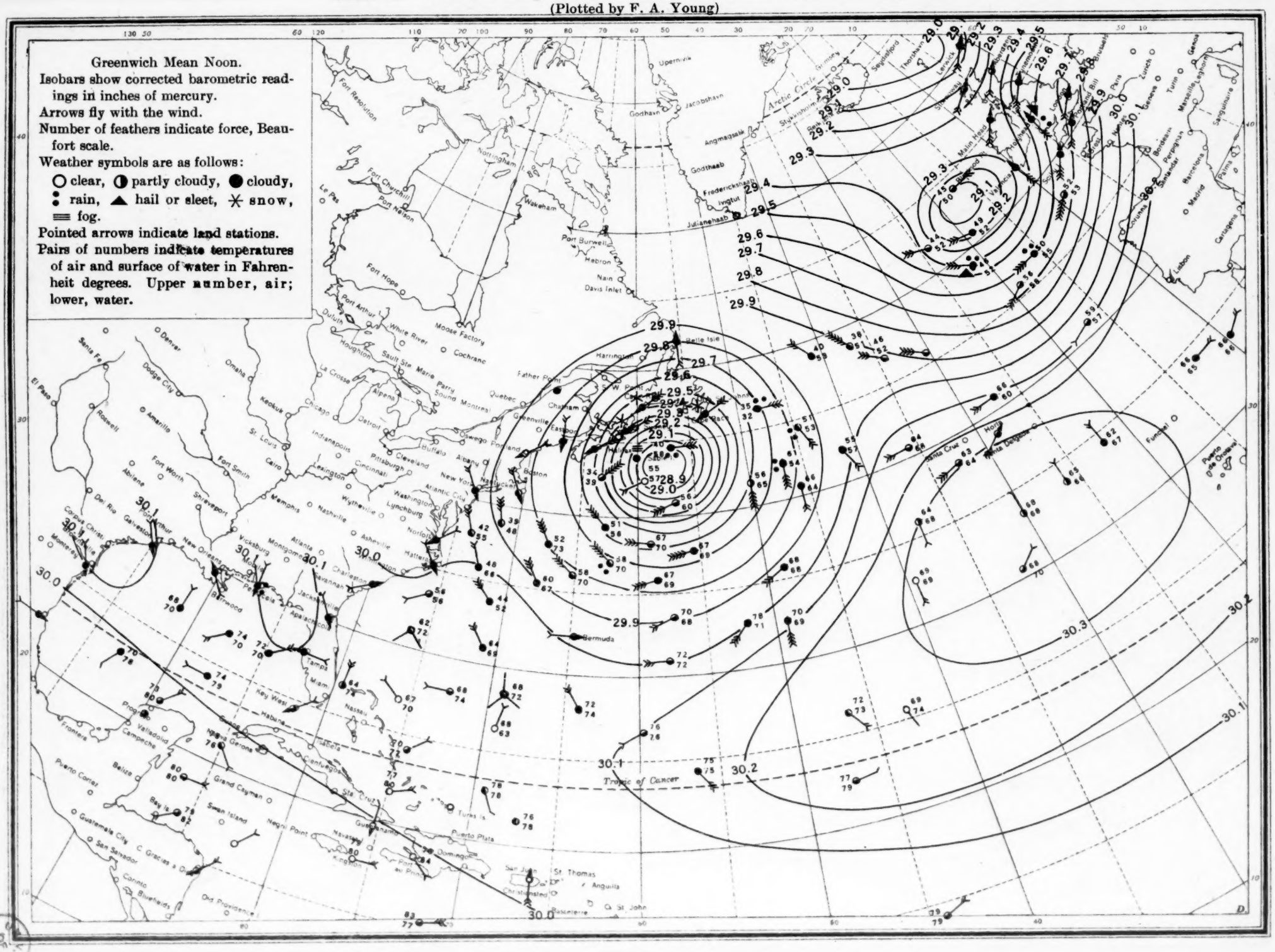
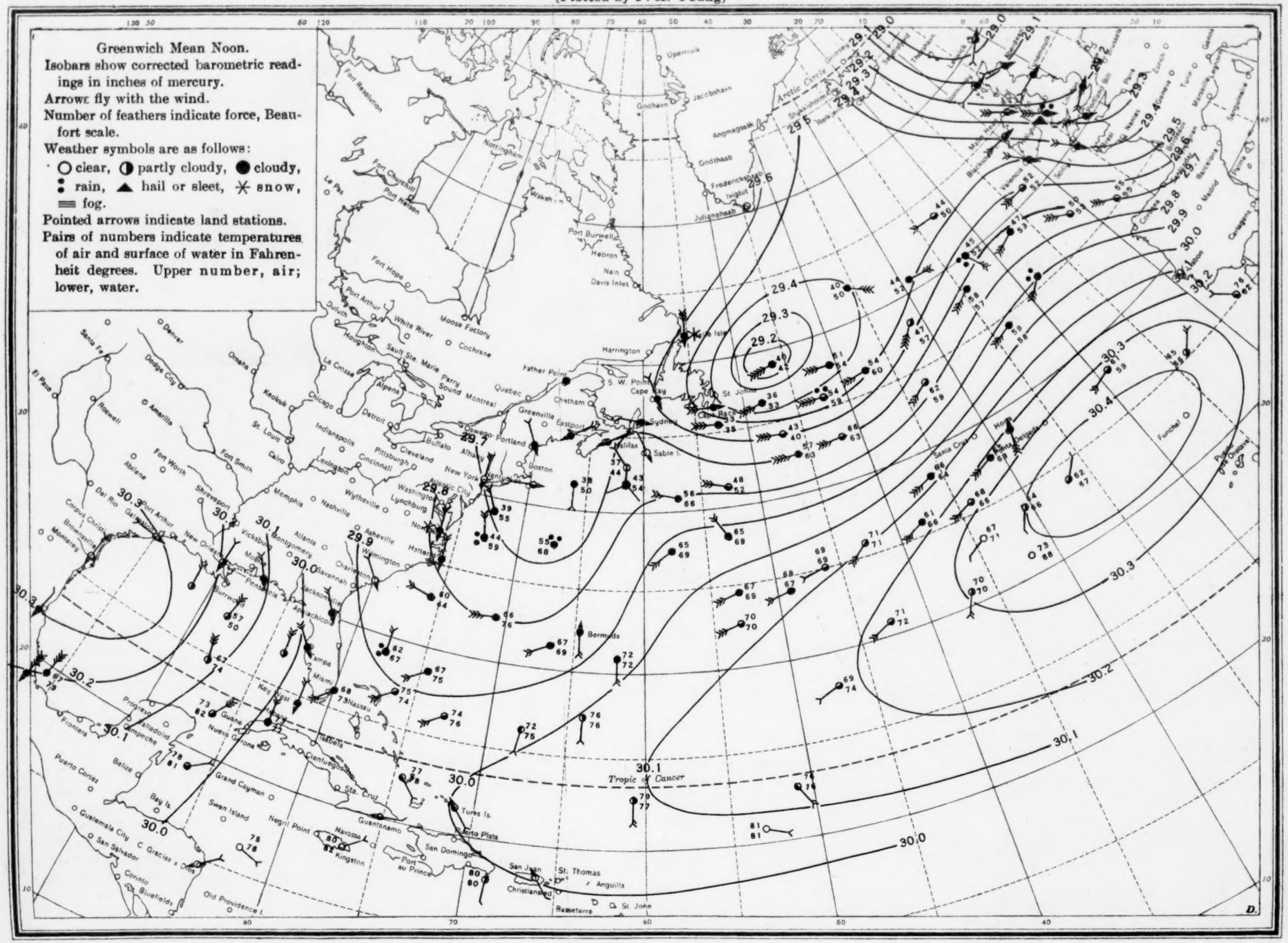

Greenwich Mean Noon.
Isobars show corrected barometric readings in inches of mercury.
Arrows fly with the wind.
Number of feathers indicate force, Beaufort scale.
Weather symbols are as follows:
○ clear, ◑ partly cloudy, ● cloudy,
⁝ rain, ▲ hail or sleet, ✳ snow,
≡ fog.
Pointed arrows indicate land stations.
Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water.
Arctic Circle
Tropic of Cancer
Bermuda
Nassau
Habana
Key West
Miami
Tampa
Jacksonville
Charleston
Hatteras
Norfolk
Atlantic City
New York
Boston
Portland
Eastport
Halifax
Sydney
Belle Isle
Harrington
Father Point
Quebec
Montreal
Sault Ste. Marie
Parry Sound
Port Arthur
Duluth
Houghton
White River
Moose Factory
Cochrane
Port Hope
Fort Churchill
Port Nelson
Le Pas
Fort Resolution
Nottingham I.
Wakeham
Port Burwell
Hebron
Nain
Davis Inlet
Godthaab
Fredericksháb
Ivigtut
Julianehaab
Angmagssalik
Godhavn
Jacobshavn
Upernivik
Stykkisholm
Seydisfjord
Thorshavn
Lerwick
Shetland Is.
Valentia
Malin Head
Roches Point
Scilly
Ushant
Brest
Paris
Zurich
Geneva
Turin
Genoa
Marseilles
Bordeaux
Perpignan
Barcelona
Santander
Madrid
Lisbon
Coruña
Cartagena
Palma
Sarguinaire
Funchal
Porto Santo
Santa Cruz
Hatteras
Santa Domingo
Puerto Plata
Turks Is.
Grand Cayman
Swan Island
Negril Point
Guantanamo
Kingston
Port au Prince
San Juan
St. Thomas
Anguilla
Christiansted
St. John
Basseterre
Puerto Cortez
Belize
Bay Is.
Guatemala City
San Salvador
C. Gracias a Dios
Corinto
Bluefields
Old Providence
Progreso
Campeche
Frontera
Veracruz
Tuxpan
Tampico
Galveston
Corpus Christi
Del Rio
Brownsville
Monterey
Abilene
Fort Worth
Shreveport
New Orleans
Vicksburg
Montgomery
Atlanta
Memphis
Nashville
Asheville
Wytheville
Lynchburg
Washington
Cincinnati
Pittsburgh
Cleveland
Buffalo
Albany
Indianapolis
Lexington
Chicago
Detroit
Alpena
Kockuk
St. Louis
Cairo
Omaha
La Crosse
Dodge City
Amarillo
Roswell
Santa Fe
El Paso
Denver
Fort Smith
Galveston
Corpus Christi
Del Rio
Monterey
Abilene
Fort Worth
Shreveport
New Orleans
Vicksburg
Montgomery
Atlanta
Memphis
Nashville
Asheville
Wytheville
Lynchburg
Washington
Cincinnati
Pittsburgh
Cleveland
Buffalo
Albany
Indianapolis
Lexington
Chicago
Detroit
Alpena
Kockuk
St. Louis
Cairo
Omaha
La Crosse
Dodge City
Amarillo
Roswell
Santa Fe
El Paso
Denver
Fort Smith
Tropic of Cancer
Bermuda
Nassau
Habana
Key West
Miami
Tampa
Jacksonville
Charleston
Hatteras
Norfolk
Atlantic City
New York
Boston
Portland
Eastport
Halifax
Sydney
Belle Isle
Harrington
Father Point
Quebec
Montreal
Sault Ste. Marie
Parry Sound
Port Arthur
Duluth
Houghton
White River
Moose Factory
Cochrane
Port Hope
Fort Churchill
Port Nelson
Le Pas
Fort Resolution
Nottingham I.
Wakeham
Port Burwell
Hebron
Nain
Davis Inlet
Godthaab
Fredericksháb
Ivigtut
Julianehaab
Angmagssalik
Godhavn
Jacobshavn
Upernivik
Stykkisholm
Seydisfjord
Thorshavn
Lerwick
Shetland Is.
Valentia
Malin Head
Roches Point
Scilly
Ushant
Brest
Paris
Zurich
Geneva
Turin
Genoa
Marseilles
Bordeaux
Perpignan
Barcelona
Santander
Madrid
Lisbon
Coruña
Cartagena
Palma
Sarguinaire
Funchal
Porto Santo
Santa Cruz
Hatteras
Santa Domingo
Puerto Plata
Turks Is.
Grand Cayman
Swan Island
Negril Point
Guantanamo
Kingston
Port au Prince
San Juan
St. Thomas
Anguilla
Christiansted
St. John
Basseterre
Puerto Cortez
Belize
Bay Is.
Guatemala City
San Salvador
C. Gracias a Dios
Corinto
Bluefields
Old Providence
Progreso
Campeche
Frontera
Veracruz
Tuxpan
Tampico
Galveston
Corpus Christi
Del Rio
Brownsville

Chart XI. Weather Map of North Atlantic Ocean, December 29, 1930

(Plotted by F. A. Young)



PUBLICATIONS OF THE U. S. WEATHER BUREAU

A list of publications, showing those for which a charge is made and those which are issued gratis, may be obtained by application to the "Chief, U. S. Weather Bureau, Washington, D. C.," to whom also requests for the publications issued gratis should be made.

To obtain publications for which there is a charge, apply to "Superintendent of Documents, Government Printing Office, Washington, D. C."

Annual subscriptions to the MONTHLY WEATHER REVIEW, $1.50; single copies, 15¢. Subscription to the REVIEW does not include the Supplements, which are issued irregularly and are for sale by the Superintendent of Documents. Supplements will usually be abstracted in the REVIEW, and the price of the particular Supplement will be there announced.

Detailed climatological data for the United States and its Territories may be purchased from the Superintendent of Documents as follows:

A volume issued monthly entitled "Climatological data for the United States, by Sections" (each section corresponding to a State, except that some small States are combined in one section), comprises all but Alaska, Hawaii, and Porto Rico. By subscription, 12 months and annual summary, $4; single months, 35¢. Individual sections, by subscription, 12 months 50¢; single, months, 5¢. The individual section prices apply to the reports of Alaskan, Hawaiian, and West Indian services, the last named including Porto Rico and the Virgin Islands.

PREPARATION OF MANUSCRIPT FOR PUBLICATION IN THIS REVIEW

The following memorandum in regard to preparing manuscripts for publication is reproduced from the regulations of the Department of Agriculture with respect to effecting economies in the public printing:

> Authors will be expected to prepare their manuscripts with the understanding that once the manuscript leaves the author's hands it is in final form and not subject to further change of text in galley or page proof. With the adoption of this policy it will be necessary that authors consult workers on related subjects in other bureaus before finally submitting their manuscripts for publication, and all matters as to which there is difference of opinion must be settled in advance.

The Weather Bureau desires that the MONTHLY WEATHER REVIEW shall be a medium of publication for contributions within its field, but the publication of a contribution is not to be construed as official approval of the views expressed.

PROOFS AND REPRINTS

In order to maintain the schedule with the Public Printer, no proofs will be sent to authors outside of Washington, D. C. Requests for a limited number of reprints of the more important contributions can be granted. Such requests should be made by the author on the first page of the manuscript.

MISSING NUMBERS

Missing numbers of the REVIEW will be supplied gratis when application therefor, addressed to Chief of Weather Bureau, is received within three months of the usual date of receipt of the missing number. Applications filed at a later date should be accompanied by the price of the REVIEWS desired, 15¢ the copy, and be addressed to the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C.

Certificate.—By direction of the Secretary of Agriculture, the matter contained herein is published as administrative and statistical information and is required for the proper transaction of the public business.

U. S. GOVERNMENT PRINTING OFFICE: 1921